SCIENCE TEACHER'S WORLD

Teacher's edition of Science World • March 24, 1959

Providing for the gifted student

Let us leave it to the educational theoreticians to define the "gifted," "science-talented," or "academically talented" student. Suffice it to say that the alert and experienced teacher, even without benefit of a definition, can spot an exceptionally good learner early in the term. Such a student is a challenge to the teacher's professional competence and is a joy to teach. On the other hand, the inexperienced or unobserving teacher who fails to take notice of such a student early enough in the term may soon lose him along the way; even worse, the teacher may find himself confronted with a bewildering disciplinary problem.

The purpose of this article is to offer a few suggestions for teaching science in such a way as to bring into play the learning assets of the gifted student — his high intelligence, his broader-than-usual range of interests, his better reading ability, and his latent drive. The suggestions:

Provide a variety of information sources. The proverb, "You can lead a horse to water, but you can't make him drink," does not apply to a *thirsty* horse. When guided to appropriate and challenging sources of information, the gifted student *will* "drink."

At the beginning of the term, show your class some sample books and periodicals that will be available in the classroom or in the school library. When beginning a unit of work, bring in appropriate literature. It is good to have a prepared mimeographed list of specific references for topics under study. But you have no assurance that the list will be used unless you refer to specific books or articles in the course of your teaching and take the trouble to write the references again on the blackboard. Assign book reports or article reviews for special credit; do not overlook extension literature — novels, poems, biographies, and travel books pertaining to your subject. Encourage students to express their reactions to this material. Their comments will guide you in constantly improving your reference lists.

Teach in depth. While it may be prudent to go easy on the use of technical terms in teaching the average or below-average learner, the bright student will thrive on them — *if* he is challenged to look up their derivation and to associate them clearly with the phenomena under consideration. Moreover, the gifted student can be led to think in conceptually enriched terms. For example, what to the average student is simply a "message" moving along a nerve fiber can be to the gifted student a chemical disturbance traveling along a fiber and producing associated electrical changes. The average chemistry student can be shown a substance coming out of solution in the form of crystals; the gifted student can be led to see, in the same phenomenon, atoms becoming structured under the influence of electrical forces.

Lead to the frontiers of knowledge. In going into any area of science, it is surprising how soon one reaches horizons and is left to conjecture about what lies beyond. How did matter come into existence? Where do cosmic rays come from? What causes cells to differentiate? Just how do genes duplicate themselves? What is the meaning of the multiplicity of atomic particles that are being discovered? What part of the brain is involved in giving us a sense of time? How

YOUNG SCIENTISTS

Teachers are urged to have their students submit write-ups of interesting projects or experiments they have done. If printed in SCIENCE WORLD, full credit will be given to the student, the school, and the teacher. In addition, the student will receive $15. Contributions should be addressed to Science Project Editor, Science World, 575 Madison Avenue, New York 22, N.Y. Students should be reminded that by submitting their ideas they can do a service to thousands of other students.

do migrating birds find their way? What is on the other side of the moon? What forms of life, if any, are found on other planets? For that matter, can any biologist explain consciousness in terms of chemical reactions or physical forces? Can any physicist tell us what electricity actually is?

The gifted student responds intellectually and emotionally to such questions as these, especially when they are raised in a context of systematic study.

Stimulate imaginative and critical thinking. After presenting data, call for comparisons and generalizations. After presenting theory, call for applications. For example, ask the student to explain the fact that dry air is heavier than an equal volume of moist air. Expose the student to a phenomenon and call for hypotheses to explain it. For example, how may we account for the fact that the tip of an oat coleoptile turns toward a burning electric light bulb? Present alternate hypotheses, and call for the design of an experiment to test them. For example, during photosynthesis, sugar is made from carbon dioxide and water. Which of these substances furnishes the oxygen for the sugar molecule?

Such stimulations can be given in the recitation period, in the laboratory (see "Toward More Effective Laboratory Work in Science," *STW*, November 11, 1958), in homework assignments ("Science Homework," *STW*, October 28, 1958), and in special project work.

Provide outlets for science activities. Encourage students to write articles for publication in student journals. Farm out special library or laboratory investigations. Assign students to interview a doctor, a druggist, an engineer, or a research scientist on questions that may arise in class and for which such consultation is appropriate. Give students the opportunity to make special reports to the class or to show and explain completed projects. Encourage students to enter science fairs.

It is to be noted that the above suggestions pertain to actual classroom teaching. It goes without saying that the teacher is in a position to marshal a great many out-of-class resources for the cultivation of the student who is gifted in science. A few are mentioned below:

THE SCIENCE CLUB. For the gifted student, the science club offers opportunities not only for active participation, but also for leadership and training in responsibility. The gifted student may be given responsibilities connected with planning programs, corresponding with speakers, publicizing meetings, conducting meetings, planning publications, and planning trips. In the club, the student may hear and converse with working scientists and may learn about areas of science that are not represented in the course of study, that go beyond what is taught in class, or that cut across subject-matter lines.

THE STUDENT SCIENCE MAGAZINE. Here is an outlet for a wide range of talent within a context of science: writing, editing, and illustrating articles, planning and writing editorials, designing the cover, planning and working up "features" such as crossword puzzles, comics, current events in science, and the like, obtaining advertisements, and managing sales. Involved also is a good deal of correspondence, meeting deadlines, keeping accounts, and, above all, real teamwork.

OUT-OF-CLASS ASSISTANCE TO THE TEACHER. The gifted student can be given the opportunity to assist the science teacher in the preparation of demonstrations and experiments, in trial runs of demonstrations, in servicing apparatus, and in maintaining live animals, plants, or microbial cultures. Wherever possible, the science preparation room should be expanded into a project room, where at least a few gifted students might work on projects of their own.

EXTRAMURAL ACTIVITIES. Keep your gifted students informed of science fair activities, science congresses, junior academies, meetings of professional and academic societies to which they may be admitted, student award programs such as those conducted by the National Science Teachers Association, science exhibitions, special TV programs, special summer programs, and scholarship opportunities.

CO-OPERATING SCIENTISTS. Both you, as a teacher, and the gifted student will get the greatest satisfaction from working together on a scientific problem. In pursuing such a problem you may well find yourself beyond your depth. In that case, call on a specialist in the field. If your experience is like mine, the specialist will join forces with both of you in a spirit of enthusiasm and delight; and you, as a teacher, will get a new thrill out of your professional life.

— ZACHARIAH SUBARSKY

Science teacher's question box

Do some insects use "insecticide spray" against other insects? — L. P. R., Chicago, Ill.

At least one insect, the cockroach *Diploptera punctata*, does. It ejects through its second abdominal spiracles a p-benzoquinone mixture that is secreted by glands within its body. This roach will usually eject the spray from the side on which it is attacked by an ant, beetle, spider, or other predator. According to Dr. T. Eisner of Cornell University, who has been studying this phenomenon, the predator is not killed by the spray. It suffers a two-minute seizure during which the cockroach makes its getaway.

How efficient are today's power-producing atomic reactors — that is, how do they compare in energy production with, say, a coal-burning furnace? — T. S., Chicago, Ill.

In reactors using metallic fuel, one ton of uranium does the work of 20,000 tons of coal.

Is there a good vital stain to improve visibility in demonstrations of plasmolysis in live onion cells? — R. P. J., Los Angeles, Calif.

Better than any vital stain is the use of *red* onions. The cytoplasm of red onion cells is naturally colored.

MEMO

To: Science teachers

Subject: Ways to use this issue of SCIENCE WORLD in the classroom

H-blast and Project Plowshare

PHYSICS TOPICS: atomic energy — fission and fusion
EARTH SCIENCE TOPICS: structure of the earth, new sources of raw materials
CHEMISTRY TOPIC: heat of formation
GENERAL SCIENCE TOPIC: peacetime uses of atomic energy

This article deals with some implications of experimental work now being done in Livermore, California, on underground H-blast explosions. We tend to associate explosions with war and violence. We are less inclined to associate them with the building of railroads, tunnels, bridges, or reservoirs. One would imagine that atomic explosions, being much more powerful than chemical explosions, would open up even greater possibilities for such peacetime uses. But the fly in the ointment is the extremely dangerous radioactivity in the wake of such explosions. This is certainly true of *fission* explosions. On the other hand, *fusion* explosions may yield enormous amounts of energy with a minimum of residual radioactivity. If the latter can be brought under control, man will have at his disposal powers that will enable him to bring about desirable geological changes in his environment that stagger the imagination. Some of these are described by Leonard Paris in this article. These possible future applications of atomic energy will appeal equally to students in physics, chemistry, earth science, or general science classes.

Discussion questions

1. What are the alleged advantages of the H-blast over the A-blast for peacetime use?
2. How do you account for the residual radioactivity after an H-blast?
3. What devices are being tried out for the control of radioactivity in an H-blast?
4. How may H-blasts be used for each of these purposes: increasing our water supply, increasing our oil supply, improving our harbors, producing chemicals, producing isotopes, and exploring the structure of the earth?

Brains and behavior

BIOLOGY, GENERAL SCIENCE TOPICS: the nervous system, behavior, reproduction, and parental care

Biology and general science teachers can use this sketch of comparative behavior — from earthworm to man — as supplementary reading for pupils studying the nervous system and behavior. The article points up the correlation between complexity of nervous system and complexity of behavior. The behavior described ranges from behavior that is almost totally inborn and automatic to behavior that is conditioned by specific environmental influences. The function of the nervous system as a mechanism for adjusting the organism to its environment is clearly indicated. Some of the experimentation described by Mr. Ames will suggest projects that students might be stimulated to undertake.

Discussion questions

1. How do you account for the fact that penguins encountered by Dr. Murphy in Antarctica showed no fear of man, but avoided the edges of ice floes?
2. When an earthworm is cut in two, each half still responds to stimuli. What is there about a worm's nervous system that may help explain this behavior?
3. You may have seen the large pear-shaped or spherical "nests" of the paper wasp hanging from a branch of a tree or under the overhang of a roof. How is such a nest started? How does it "grow"?
4. What evidence is there that an earthworm *can* learn?
5. What evidence is there that each of the following is performed automatically and without "intelligence": a worker-wasp feeding larvae, a warbler feeding its nestlings, a fawn following its mother, a newborn turtle finding a body of water?
6. What evidence indicates that the following statement is true: even animals with very highly developed nervous systems show behavior that is inborn and automatic?

Projects and experiments

1. Construct a T-maze and repeat the experiment described in this article; find out whether an earthworm can learn.

2. Collect several earthworms and place them in a shallow pan of moist moss. Cover the top so that the worms will be in the dark. After a while, lift the cover at one end and shine a flashlight on the worms from that end. Observe in which direction the worms move. Lift the cover off the other end and shine a flashlight into that end. Observe the direction of movement of the worms.

3. Using the observations you make in the above experiment, design an experiment to see if you can teach an earthworm to avoid going into one of two holes in soil.

4. Construct a rat-maze with one entrance and two exits. See if you can teach a rat to avoid leaving by *one* of the exits.

Light from the past

Physics topics: radioactivity, crystallography, thermoluminescence, cosmic rays

Chemistry topic: isotopes

Earth science topics: age of the earth, petrology

General science topics: age of the earth, carbon dating, peacetime uses of atomic energy

Science teachers should — and usually do — include in their teaching some accounts of *current* research. But if such accounts are limited to "success" stories, the teacher may unwittingly give his students a distorted and erroneous impression of the scientific enterprise. Students should be made aware that a real "find" in research is the exception, not the rule; that persistent perplexities and even frustrations are what the researcher faces day by day.

Through this article, the science teacher can bring home to his students the fact that patience, stick-to-itiveness, and courage in the face of frustration are important and necessary ingredients in the character of the first-rate worker in scientific research. The concluding sentence of the article hits the nail on the head: "One hit, one miss — in scientific experiments this is a very good batting average, indeed."

Discussion questions

1. How does the mass spectrometer serve as a "dating" tool?

2. Why is the carbon-dating method limited to substances not older than 50,000 years?

3. What doubt is there about the absolute accuracy of the carbon-dating method?

4. Under what conditions was thermoluminescence discovered before Dr. Zeller came into the picture?

5. How do present-day physicists account for thermoluminescence?

6. What is the theory behind Dr. Zeller's method for determining the age of a substance?

7. How does Dr. Zeller's method of dating by thermoluminescence work?

8. How was Dr. Zeller's method applied to try to determine the age of antarctic ice? Why was this experiment unsuccessful?

The spaceship's gardener

Biology topics: photosynthesis, algae, nutrition

Chemistry topics: oxidation and reduction, organic chemistry

General science topics: the water cycle, the carbon cycle, the nitrogen cycle, water purification

Dr. Asimov describes a veritable microcosm that is to be built into a spaceship for the purpose of sustaining life on long space voyages over indefinitely long periods of time. In this microcosm, substances bearing energy would circulate through the living bodies of crewmen and through the spaceship's contained atmosphere in a way similar to that in which they circulate through the bodies of earthbound organisms and through the natural atmosphere. Students in biology, chemistry, or general science classes can be led to ponder this weird "application" in connection with any of the topics listed above. But it will take some recent reports in the newspapers to convince them that they are not dealing with science fiction.

Discussion questions

1. How might each of these problems be solved in a spaceship: (a) the accumulation of exhaled carbon dioxide; (b) the need for drinking water; (c) the accumulation of body wastes; (d) the need for food?

2. What are the advantages of algae over other plants for spaceship gardening?

3. How would the required weight of algae differ with respect to (1) the number of crewmen and (2) the length of the trip?

Suggested activities

1. Look up methods of growing *Chlorella,* and grow some.

2. Examine some cells of *Chlorella* under the high-power lens of a microscope. Find chloroplasts.

3. Set up an experiment to find out whether a mass of *Chlorella* can keep fruit flies supplied with needed oxygen.

Flash lamps, but no pictures

Chemistry topics: polyethylene plastics, pyrolysis, relation between pure and applied research

Physics topics: heat absorption, fluorescence

It is widely recognized that applied research depends heavily on the findings of "pure" research. But here in this article is a case of real "feedback." In the pursuit of the causes of an accidental explosion that took place in the course of an "applied" investigation, not only was a new tool brought forth — the flash pyrometer — but there emerged a whole field of perplexing phenomena that will attract many investigators interested in "pure" research for some time to come. Whether in pure or in applied research, serendipity pays off.

Discussion questions

1. How does polyethylene resemble wax in chemical structure?

2. How can you explain the emission of gases when polyethylene is subjected to intense light?

3. In flash-pyrolysis research, what materials are used for inert "black bodies"? For inert "matrices"?

4. What "practical applications" may be made of flash pyrolysis in the future?

SCIENCE WORLD

MARCH 24, 1959

THE SCIENCE MAGAZINE FOR HIGH SCHOOL STUDENTS

Danger in the water safety on land (see page 4)

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SCIENCE WORLD

THE SCIENCE MAGAZINE FOR HIGH SCHOOL STUDENTS

The Staff

Coming in SW, April 7

How are scientists planning to build an electrical power plant on the moon? How will its power facilitate living on the earth's natural satellite?
What are the current theories on the origin of giant meteors?
In what ways is "silent sound" being put to work in homes and factories?
Why do courageous scientists hunt viruses in the Amazon Valley of Brazil?
For answers, see next issue of *SW*.

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Features

Science Fiction

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Cover by William Bartlett

About the contributors

GERALD AMES (page 4) and his wife Rose Wyler recently did some experimenting of their own with brains and behavior *(see photo)*. The baby chimp proved an apt learner—but the husband-wife team must still write their own articles. LEONARD PARIS (page 8) is a former high school teacher turned writer and editor. He is now editor of *Monsanto Magazine* in St. Louis. JAMES E. GUNN (page 14), long familiar as a contributor of *SW* science fiction, here turns to science reporting.

By Gerald Ames

Why is a penguin fearless on land?

How does an earthworm sense your presence?

How do baby turtles find water?

The answers are found in scientific studies of

Brains and behavior

■ When the naturalist Robert Cushman Murphy was "ambassador to the penguins" on South Georgia Island in the antarctic, he marveled at how well the birds' behavior was adapted to cope with the dangers of their world.

The reception they gave Dr. Murphy was revealing. When he appeared, the penguins — gentoos — let him walk among them and showed not the slightest sign of alarm. Why should they? They had never been hunted by man, or, for that matter, by any animal that walked on land or ice. Their great enemy, the leopard seal, lurked in the sea.

When pursued by the leopard seal, penguins would speed to the nearest land or ice and, with one long leap, shoot up to a ledge and safety. To them, danger was associated with the sea; safety, with land or ice. When the "ambassador" tried to chase them into the sea, where they might easily have evaded him, they ran clumsily away from the water. This was their standard defense against their usual enemy — and a good defense it was, judging from the fact that penguins had managed to survive and multiply in spite of the vicious leopard seals.

Behavior has evolved through the ages, as bodies have, but its history cannot be traced by comparing fossils. Instead, scientists compare living animals of different types, from the simple to the complex. Even a few examples show how various forms of behavior have helped animal species adapt to their environments.

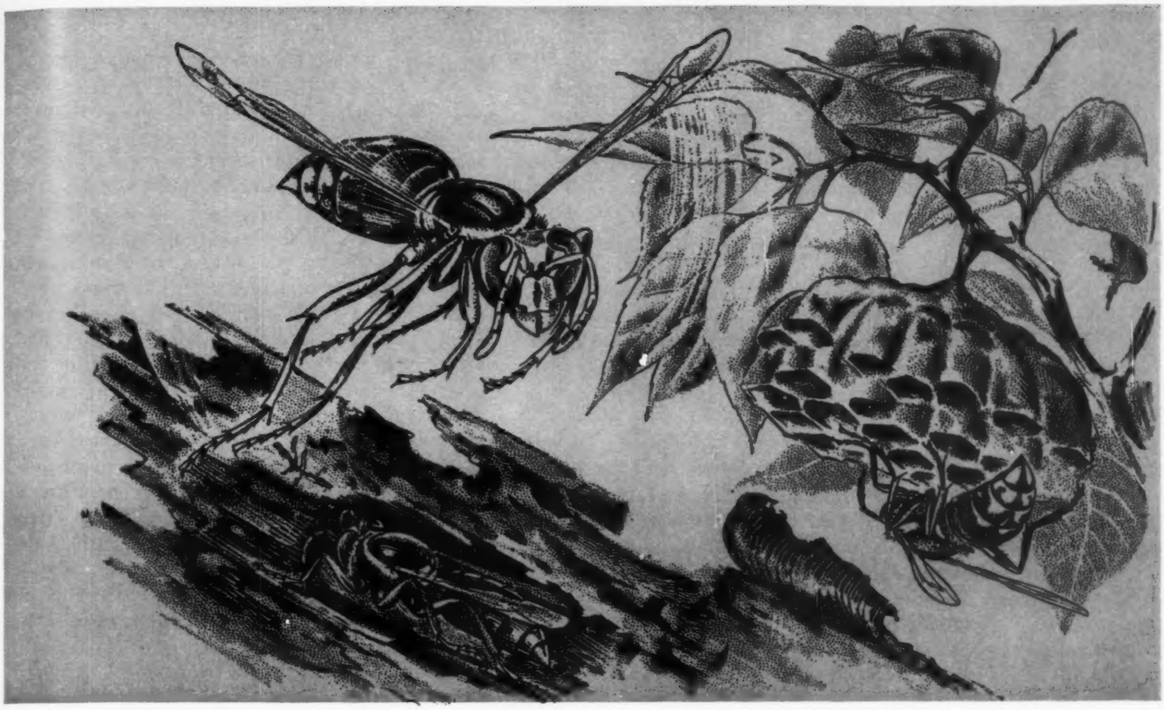
Consider the earthworm, a creature whose behavior is not very complicated and whose intelligence is not very high. Yet, if you have ever hunted night-crawlers, you know they have defenses. With flashlight in hand, you tiptoe up to a worm and grab for it; but all you get, more often than not, is a handful of grass. The worm has zipped down its hole to safety.

Without eyes and ears, how did the worm "know" you were there?

In each of its segments, the worm has a ganglion — a bunch of nerve cells with fibers going out toward the skin. The many ganglia are connected by a cord running through the entire body. This system is the worm's burglar alarm. A signal such as a temperature change or vibration causes an electrochemical impulse to shoot through the nerve fibers into the ganglia. Quickly, a message goes out to all parts of the worm, causing it to pull away from danger. The system works automatically, without any need for thought. (The worm does have a bigger front ganglion called a brain, but if this is removed the animal gets along as well as before.)

At the worm's level, behavior is guided almost entirely by instinct. This is a kind of built-in "memory" inherited from ancestors who have acted in the same way for thousands or millions of years. Every worm carries instructions for wormlike behavior coded in the hereditary material of its cells.

But even a worm can go a little beyond instinctive behavior — with some help. This has been proved by several experimenters, whose method is to put a worm through a simple intelligence test. A tube is



FEMALE WHITE-FACED WASP starts building nest in spring and raises female workers. They take over job of enlarging nest.

built — an artificial wormhole — in the shape of the letter T. In the test, the worm is placed in the tube opening and starts crawling. When it reaches the crossing, it can turn either to the right, where the passage is safe, or to the left, where there are electrodes that will give it a slight shock.

The worm begins by taking one route as often as the other. Day after day, it gets shocks because it repeats the same old mistake. The worm seems unable to remember and benefit from experience. But at last, after many trials, it begins to take the good route more often than the bad. The worm has learned!

Insects have more complex bodies and nervous systems than worms, and they behave in more complex ways. The white-faced wasp or hornet, using its enormous eyes for navigation, goes on long flights to find food and nest-building material. With its antennae, it picks up the odors of food and the scent of fellow wasps.

In autumn, frost kills all male and unmated female wasps. But there are some mated females that have crept into rotted logs or other shelters to hibernate. When spring comes, each female crawls out into the light and starts building a nest, where she will be "queen."

The queen gathers bits of wood and chews them into pulp. With the pulp, she begins to build a paper nest on a branch. At first it is just a little cluster of chambers in which she lays eggs. Grubs hatch from them and, after two changes in form, develop into female workers. The queen continues to lay eggs, while the workers feed the new batches of grubs and also enlarge the nest.

Can such a complicated organization function without reason and planning? A famous incident suggests that wasps, for all their talents, do not think. When a scientist shut up a worker wasp with a grub but no food, the worker bit the grub in two and offered the hind end to the front end. Evidently, wasp behavior is directed by inborn instructions operating in set ways.

Coming to the vertebrates, we find that the behavior of many of them is still largely instinctive. The painted turtle gives us an example of automatic responses in a reptile. Young turtles start out in life without parental guidance in conduct. Hatching from eggs deserted by the mother, the little turtles take one glance at the world and know what to do. They crawl off toward the brightest light, which is usually where water lies.

Warm-blooded animals are generally quicker and more resourceful than cold-blooded, for their high rate of metabolism makes nerve impulses go faster and brains work better. But warm-bloodedness brings problems along with advantages. Young birds, unlike turtles, cannot be left alone. They are unable to feed themselves, and their system of temperature control isn't in working order until some while after hatching. So they need heat from outside, and it is supplied by the parents.

Newly hatched warblers are blind, naked, and unable to do anything but open their beaks for food.

When the parent lands on the nest, the shaking of the nest causes them to open their beaks wide. This prompts the parent to cram food into them.

The parent gives the young ones excellent care, but almost automatically. This is shown by an accident that sometimes happens to a warbler family. Once the eggs are in the nest, a cowbird may sneak up and lay its own egg among them. The cowbird's egg is bigger than the warbler's, but the warbler doesn't mind. It broods the strange egg along with its own, until there is a nestful of little warblers and a bigger cowbird. Soon the young cowbird shoves the baby warblers out. They fall to the ground and lie there dying of chill and hunger, but the parent seems unconcerned. In the nest there is still a beak gaping, a voice clamoring for food. So the warbler goes on gathering food to fill the beak, since this is what its instinct commands.

Mammals are carried in their mothers' bodies for varying periods of time. At birth, the brain of a young mammal — even the brain of a mouse — is large in relation to its body size. But at first the brain is in a highly unfinished state. The nerve cells and fibers are there, but connections must be made between them as the young animal develops. The unfinished condition of the brain leaves room for future learning.

Newborn mammals have the instinct to suck, but can do little or nothing else. A fawn, less helpless than many others, manages to stand or kneel when sucking. While its mother is away, the fawn lies still under the cover of grass or shrubs, without knowing that this is the way to hide from enemies. At first it acts according to inborn instructions; but soon the fawn will have adventures in the world, and will learn from them.

Sometimes a fawn has the unusual experience of being adopted by a human being, who feeds it from a bottle. To the fawn, this person becomes mother. It follows the foster mother, and other people, too, as if following a herd of its own kind.

A young deer that grows up in this way can never be turned loose to live in the wild. Unable to tell enemy from friend, it would probably walk right up to a hunter or to a wolf. It would be killed before it had a chance to learn the ways in which wild deer protect themselves.

In the wild, a half-grown fawn is led by its mother to the herd. Following her, it follows the herd and does what the older animals do. When they see or scent danger and run, the fawn runs. Thus it learns to recognize danger and save itself.

Among carnivores, training is more extensive; for carnivores are hunters, and hunting takes skill. Lion cubs begin their education at the nursery school stage. At first, it is all play. Instinctively using their claws, muscles, and senses, they stalk and pounce on one another or on their mother's twitching tail.

Step by step, learning is added to instinct, until it becomes hard to draw a line between the learned elements of behavior and the instinctive ones The cubs follow their mother, watch as she hunts, and try it themselves. They are clumsy at first, but soon improve.

Their training lasts about a year and a half — not because they are stupid, but because there is so much to learn. They must know where and what to hunt and how to stalk big grazing animals in order to get close enough for the final rush. While in training, the young lions form the habit of working as a group, and will hunt by teamwork for the rest of their lives.

Among monkeys and apes, development of the young is slow, and parental care and training must continue for a long time. When the different primate groups are compared, we find that bigger brains and higher intelligence are connected with slower development of the young. Even before birth, the creature with the better brain develops more slowly. An unborn lemur is carried by its mother for four months; a monkey for five months; a chimpanzee for eight months.

After birth, as before, the different primates develop at different rates. The lemur walks in a few days and is grown-up in a year. The monkey walks in a month and is grown-up in three years. The chimpanzee doesn't walk by itself until it is six months old and is not an adult until the age of eight years.

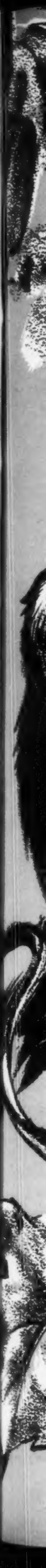
It is important for a young chimpanzee to have a long childhood under the care and protection of adults. At birth, a baby chimp can only suck and grasp. It clings tightly with hands and feet to its mother's body. If it doesn't find her breast, she takes it gently and places it there. She often cuddles the infant and sometimes tickles it.

Other animals may train their young without thinking, just by doing what they always do. But a mother chimpanzee deliberately teaches her infant. When the baby is about three months old, she gives it stretching exercises. Lying on her back, she takes its hands and feet in hers, lifts it in the air, and gently pulls its arms and legs out straight. Soon this exercise becomes a lesson in standing. The mother uses her hands to hold the baby's feet against her chest and with her own feet takes the baby by its hands and pulls it upright.

Month after month, the baby's training goes on, until it has learned to crawl, walk, climb, and swing. But the little chimp still needs care. When frightened, it runs and clings to its mother or some other adult. For several years longer it must have the protection of adults while growing and learning how to take care of itself.

Of all creatures, the one that takes longest to develop and grow up is a human child. And no wonder, considering the many things a child has to learn. After crawling and walking comes speech, the skill that distinguishes a human being.

Thousands of words, thousands of ways of using them, must be understood, remembered, practiced. Each new experience, with words and other things, makes a new connection or series of connections in the brain. Development is slow, as it must be, to allow for the storing of all knowledge needed by an adult human being.



YOUNG CHIMPANZEE 'runs' to mother when frightened, just as children do.

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MAN-MADE HARBOR and channel in Alaska, as shown in artist's conception, might be dug with H-blasts. Project is now under study.

The H-blast and Project Plowshare

By Leonard Paris

■ LIVERMORE, CALIF. — Scientists at the University of California Radiation Laboratory in this pleasant, mountain-ringed town are engaged in Project Plowshare — a series of studies and tests that stagger the imagination. All hinge on peaceful uses of underground hydrogen explosions.

Such explosions would be relatively cheap. They could be made, say the scientists, with greatly reduced fission yield per unit of energy (so-called clean explosions). And they have many potentialities for peacetime applications.

With the heat and power generated by a hydrogen explosion, man can run machinery, cause oil to flow, bring about specified chemical reactions, and manufacture radioactive isotopes in enormous quantities. These things have been known or believed for some time. But the problems are many and huge. Dr. Edward Teller, the distinguished nuclear physicist, is director of the laboratory at Livermore (operated by the University of California for the Atomic Energy Commission). According to Dr. Teller, Project Plowshare is attempting to discover which of the possible benefits are only theory and which will work out in actual practice.

Dr. Gerald Johnson, an associate director closely identified with Project Plowshare, says: "[In order to accomplish these wonders for a world at peace] we must minimize the possibilities of radioactive contamination. Hence the very great

SW Editor's note:

Scientists in nuclear physics by no means agree on whether it is desirable to use underground hydrogen explosions for peaceful purposes. Some, like those quoted in this article, hail the benefits of such explosions. Others fear that *any* radioactivity added to the atmosphere poses a hazard to man.

The nations of East and West also disagree on the matter. They are holding talks in Geneva, Switzerland, that could eventually lead to a ban on nuclear weapons tests. The Soviet Union says it wants *all* nuclear explosions included in such a ban. The reason given: H-blasts tagged for peaceful purposes could mask experimentation with military weapons. The U.S. Government, arguing that adequate safeguards against this can be set up, wants non-military blasts excluded from such a ban.

Whatever the outcome of these talks, and whatever the merits of the arguments pro and con, the scientific story of how such explosions could be used for peaceful purposes is a fascinating one.

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importance of our work on attaining explosives with a lower fission yield per unit of energy."

Some of Project Plowshare's paper plans are already known to be practical. The creation of artificial harbors and channels, for instance, might be feasible and economical with underground hydrogen explosions. By synchronizing a series of carefully spaced explosions, an entire channel could be dug in a single blast. An explosion of at least a megaton (equivalent to one million tons of TNT) in magnitude would hollow out a harbor 300 feet deep at the channel's end. The excavation costs for the entire job, Dr. Johnson estimates, might be about one-tenth of the cost of conventional methods. For the heavy hydrogen fuel required is inexhaustible in supply and thus comparatively cheap.

What about the danger of contaminating the water? This is the question that absorbs much of the planners' time and energy. But Dr. Johnson says that studies are continually being made on the subject of devices with low fission-to-fusion yields. (Fission is the villain in radioactivity. Hydrogen explosions are not fission, but fusion reactions. For the difference between them, see "A Nuclear Primer" on this page.)

Other problems remain to be solved. For example, in any surface removal job, such as building a harbor, the earth that is removed must go somewhere. In a hydrogen explosion, the earth goes into the air and is carried by the wind. All the more reason for continued work on "clean" explosions, Dr. Johnson repeats.

Important strides are being made in the control of radioactive contamination, Dr. Johnson points out. For instance, activation of soil and sea water could be avoided by wrapping an explosive device in a "blanket" of boric acid. Boron soaks up the neutrons and prevents them from producing radioactivity.

One of the most exciting prospects offered by Project Plowshare is an increase in our supplies of oil.

A hydrogen explosion under an area known to contain tar sands would generate terrific heat. As a result, the oil trapped there, normally too viscous to be worked, would flow freely. This is an enormous potential. In one known area, the Athabasca Lake district of northern Canada, there are oil tars worth something like $100 million per square mile per hundred foot thickness. All that is needed is an economical method of extracting the oil. The H-blast may be it.

Another vast source of oil is in shale formations. Up to now it has not been profitable to go after this oil. It costs too much to mine the shale, heat it to extract the oil, and then dispose of the vast quantity of residue rock. But a hydrogen explosion under oil-bearing shales would heat the formation in place, free the oil for pumping, and eliminate the enormous waste disposal problem.

Another way of getting the shale oil would be to use the H-blast for surface removal. The shale could then be worked in a form of strip-mining. Strip-mining shale is not yet a profitable operation, but experts believe it can be.

Shale oil reserves are enormous. There are an estimated 700 billion barrels in this country alone. So the prospect here is a most inviting one.

The rock-crushing potential of underground explosions is one of the most interesting parts of the study. An underground atomic blast set off in Nevada in 1957 proved that a great volume of rock could be crushed while radioactivity was contained in a surrounding silicate medium. A possible future application of this idea holds great promise for some of the world's arid regions.

In such areas, what little rain does fall runs off because the ground is impermeable to water. A hydrogen explosion, by crushing the rock, would allow water to pass through the ground and be stored

A nuclear primer

The atom is the basic building block of all matter. It has a nucleus, made up of one or more protons and one or more neutrons, which are fantastically small particles. Around the nucleus whirl one or more electrons — other small particles.

The protons and neutrons in the nucleus are held in place by very powerful forces. These forces can be released and put to work.

The nucleus of the atom in uranium and certain other metals is very unstable. When conditions are proper, neutrons breaking away from the nuclei strike other nuclei and cause them to break up. This releases other neutrons, which split still more nuclei.

This chain reaction is called *fission*.

When fission occurs, tremendous quantities of heat and fast-moving particles are released. Fission is the reaction that makes an atomic bomb explode. Controlled, sustained fission is the process taking place in a nuclear reactor.

Fusion is a nuclear reaction in which the nuclei of two atoms are fused (merged). In nature, this is the reaction taking place in the sun and in the stars. Nuclei of hydrogen fuse together, forming helium nuclei. Enough energy is left over to release enormous heat. Fusion is also the reaction that takes place in a hydrogen-bomb explosion.

in huge underground aquifers, or reservoirs. According to Dr. Harold Brown, an associate director at Livermore, an explosion of one megaton would break up enough volume to allow for storage of as much as 10 billion cubic feet of water — or 70 billion gallons.

As in all Plowshare projects, it is vital that the explosions be virtually free of fission products. They must also be big — measurable in megatons — and they must be deep. The bigger the explosion, the less it costs per kiloton.

Underground heat reservoirs offer another stirring challenge to the planners. An underground H-blast generates a terrific amount of heat. If this heat can be stored in large underground cavities, it will provide an important source of power. Water could be introduced and drawn off as steam. Or perhaps carbon dioxide or nitrogen could be used as heat transfer agents. Possibly no underground cavity is needed. Maybe it is enough to shatter the rock and then just bubble a gas through it to get the heat and energy out.

At any rate, it seems fairly certain that even a one-megaton explosion would confine appreciable amounts of heat within a fairly small area for months or even years. This would provide a highly efficient source of power that would require very little capital outlay. "*If* it works," cautions Dr. Brown.

Another source of power is the great number of radioactive isotopes that could be produced by underground hydrogen explosions if suitable blanket material were used. At present, such isotopes are manufactured in small quantities in reactors. These are enough to meet our present needs for medicine, agriculture, and industry. But underground H-blasts could produce them in such huge quantities that they could act as an energy source. They would have the added advantage of being extremely light and requiring much less shielding.

The tremendous heat generated by the underground H-blasts offers other interesting possibilities. By the simple process of heating certain materials above their decomposition point, it may be possible to extract separately useful products. For instance, a shot in limestone ($CaCO_3$) would result in the production of calcium oxide (CaO) and carbon dioxide (CO_2). Both are valuable in themselves. There is also the intriguing possibility of making fresh water in enormous quantities out of sea water. It could be done by utilizing the hydrogen explosion's heat-generating properties. This is still only in discussion stages.

Finally there is the great contribution to scientific knowledge — particularly geological knowledge — through the seismic effects of an underground hydrogen explosion. Information about the earth's structure can be precisely read from the seismic waves created by such a blast. This reward alone is enough for many scientists.

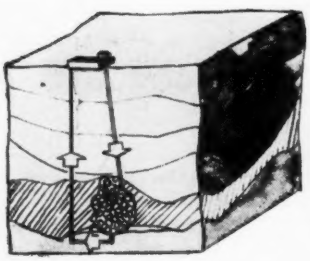
The men at Livermore view their Project Plowshare with great hope and optimism, but with typical scientific caution. The important thing to them is that we *continue* to learn all we can about the peacetime applications of nuclear power.

As Dr. Teller points out: "It is not unusual that any new source of energy should be first used for destructive purposes. That has been true all through history. It is only later — much, much later — that peaceful uses are thought of.

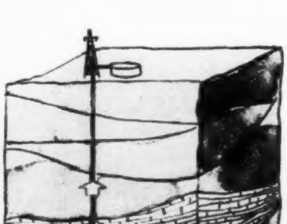
"When the hydrogen explosion was first considered, it looked as though it could not be used for any purpose save destruction. Now we see that it *can* serve peaceful purposes as well, for two reasons. One, it offers the possibility of cleaner explosions. Two, its energy source is dirt cheap."

Although only a fraction of the Radiation Laboratory's total effort now goes into Project Plowshare, the men at Livermore are convinced that its promise is the greatest one of all: a world in which there is constructive work to do, with plowshares beaten from swords.

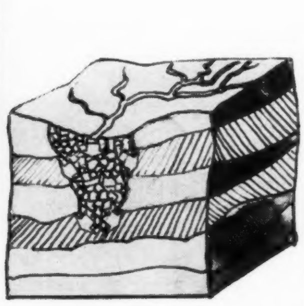
— Illustration from Monsanto Magazine



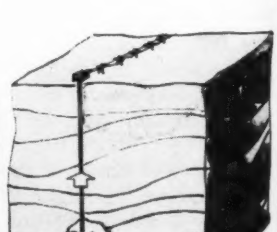
LOW-GRADE ORE DEPOSITS could be broken up by underground H-blast. Fluid could be run through crushed rock to draw off certain soluble minerals.



OIL TRAPPED IN SHALE could be extracted by heat of H-blast and pumped to surface. This would eliminate costly shale-mining methods.



ARTIFICIAL RESERVOIRS could be created in arid regions by hydrogen explosions. These would break up ground so that water could pass through.



TERRIFIC HEAT from hydrogen blast could be stored in underground cavity and drawn off to provide an important source of power.

The crew of an interplanetary spaceship

will depend on a 'closed system' for food, water, and air.

The man in charge of this will be

The spaceship's gardener

By Isaac Asimov

■ The most important man on an interplanetary spaceship may well be the gardener. His garden won't contain flowers, grass, or even weeds. It will be a thick, green soup of water and little living cells. The life or death of the spaceship crew will hinge on that garden.

A ship in space is, in effect, a little planet. As in the case of Earth (a bigger planet), its food, water, and air are limited. On Earth, these are replaced as they are used up. On a spaceship, food, water, and air will also have to be replaced. The only way of doing this that seems possible (these days) is to imitate the system that does the job on the earth.

For instance, some of the fresh water on Earth is continually being absorbed by plants or drunk by animals. Some of this is expelled into the atmosphere in the form of vapor, but much of it is expelled by animals as unusable liquid wastes.

Generally speaking, fresh water that is not used either evaporates or runs off the land into the undrinkable salt ocean. In just a short time, it would seem, all the fresh water should be gone and life on land at an end.

Fortunately, the heat of the sun is constantly evaporating the oceans. Only the water is evaporated, not the solid contents. So, though oceans are salty, the water vapor rising from them is fresh. The water vapor is lifted high in the atmosphere and falls again as rain or snow. The fresh water on land is thus continually replenished and has never been used up.

This is an example of a "cyclic process," because it moves in a circle from fresh water to ocean and back to fresh water. It is also called a "closed system," because, in the long run, nothing is lost. Both ocean and fresh water remain at the same level.

Another example involves the oxygen of the air, which is continually being absorbed by animals (and by plants, too). Within the organism, it is combined with carbohydrates and other substances to produce the energy necessary to life. In the process, carbon dioxide and water vapor are formed and discharged into the atmosphere.

The water vapor, of course, eventually falls as rain. But what about the carbon dioxide? Does it accum-

ulate forever? Does the oxygen in the atmosphere get used up?

Thanks to photosynthesis — no. In the presence of sunlight, green plants absorb carbon dioxide from the air. They combine it with water to form carbohydrates and the other components of living tissue. In this process, oxygen atoms are left over; these are given up to the atmosphere.

The proteins in animal tissue are constantly being broken down, too. These breakdown products appear in animal wastes. The wastes are made use of by plants (the wastes are "fertilizers," since they make plants grow more quickly). They are built back to protein, which animals can then eat, thus replacing what they have lost.

As you see, nothing is really used up except the sun's heat and light. As long as the sun lasts, the earth will always have a supply of food, oxygen, and fresh water.

On a spaceship, a closed system like Earth's must be set up. Some parts of it can be handled by physical or chemical methods. For instance, the water supply can be replaced. The water vapor in the air, resulting from perspiration and breathing, can be frozen out of the air by passing the circulating air over refrigerated pipes and allowing ice to collect. The ice can be mixed with liquid wastes. When the mixture is carefully heated, the water vapor given off can be collected (this process is called distillation) and used by the crew. This may sound unpleasant, but it is what happens on Earth. With care and good controls, the fresh water that results will be perfectly pure.

The carbon dioxide exhaled by the crew can be absorbed by chemicals. To save weight, chemicals must be chosen to absorb as much carbon dioxide per pound as possible. Almost the best is lithium oxide. One and a half pounds of that chemical can take care of one man's exhaled carbon dioxide for a whole day. However, once the lithium oxide has become saturated, it must, for practical reasons, be discarded.

Another chemical, calcium oxide, is a possible alternative. It would be required in slightly larger quantities, but it has this advantage: once it is saturated, it can be heated and the carbon dioxide is given up again. The carbon dioxide can be collected and stored, while the calcium oxide can then be used over. In fact, the same amount of calcium oxide can be used indefinitely.

So far, so good. Water can be replaced and carbon dioxide removed. But how will the food and oxygen be replaced? For this, plants must be grown on board the spaceship. Science does not yet know any other possibility.

Since there is little room on a spaceship, stalks, roots, flowers, or anything else that doesn't contain chlorophyll and/or isn't edible would be considered waste.

The plants that best fill the bill are certain kinds of algae — those kinds in which each tiny plant consists of one hard-working green cell. Some can be made to grow quite rapidly and to store high percentages of fat and protein. Since they possess no stalks, roots, or flowers, there is practically no waste.

Algae have already been put to the test. The School of Aviation Medicine at the Randolph Air Force Base in Texas has kept four mice alive for two to three weeks in a closed container, using algae to keep the air fresh.

Suppose we imagine ourselves aboard a spaceship with such an algae system. How does it work?

First, there's a calcium oxide chamber, which collects carbon dioxide out of the air circulated through it. Some of the calcium oxide is heated to release the carbon dioxide, which is then bubbled through a large water tank filled with algae.

Urea is also added to the tank. Urea is a fertilizing chemical containing nitrogen. It is left over when water (and salt) is removed from liquid wastes. Solid wastes also contain nitrogen compounds that may be added. The solid wastes, however, must first be treated with ultraviolet light to kill the bacteria present.

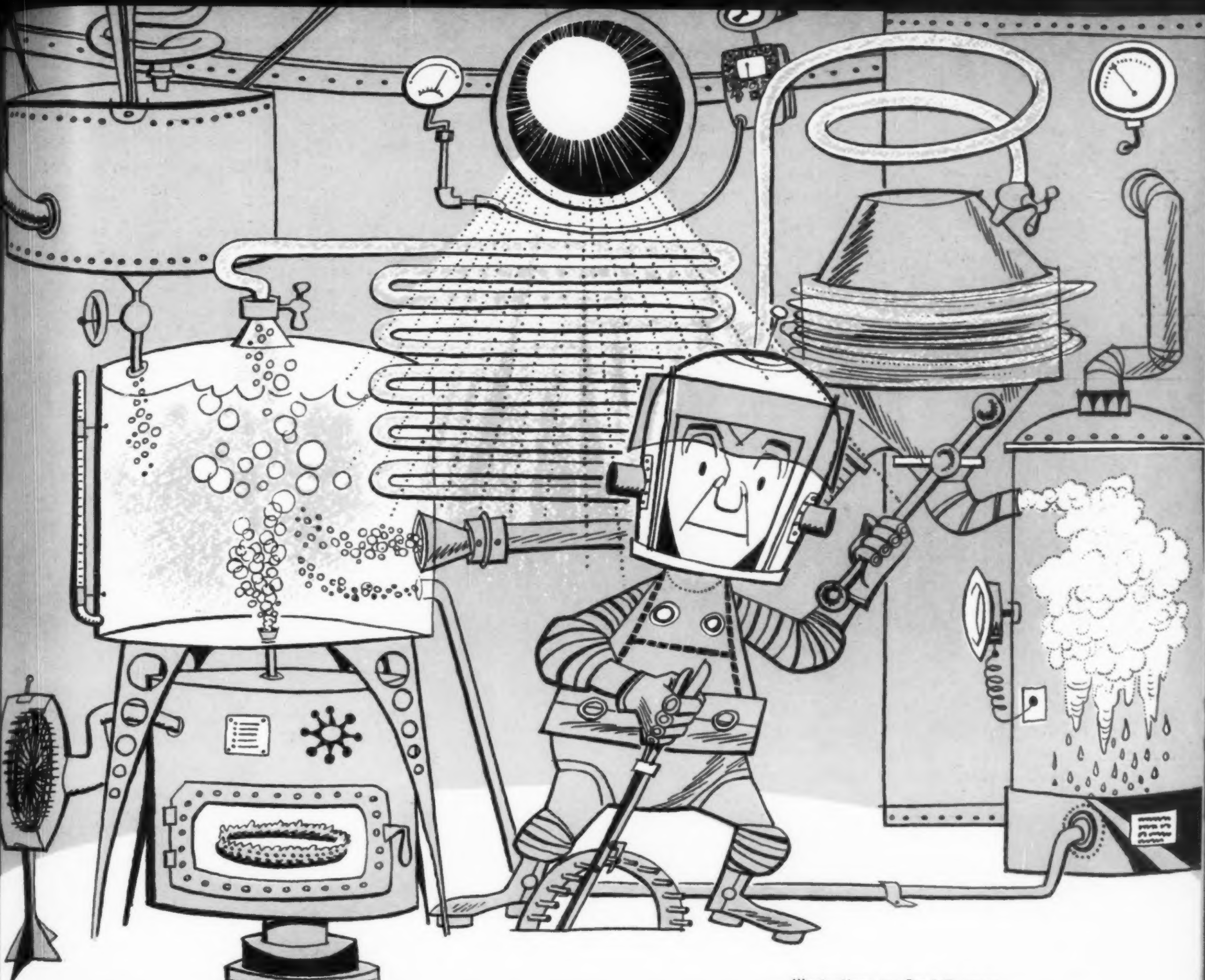
The algae (with carbon-dioxide and nitrogen compounds added) are then circulated through shallow, transparent-walled pipes. And the pipes are exposed to light. If the spaceship is near a sun, filtered sunlight would be ideal. Otherwise, fluorescent lights can be used. In the presence of light, the algae combine carbon dioxide, water, and nitrogen compounds and form oxygen, carbohydrates, fat, protein and vitamins. In doing so, they grow and multiply. The extra algae could be used as food.

After having passed through the lighted pipes, the algae are led back to the main vat for another supply of carbon dioxide and nitrogen compounds. On the way, though, they are run through a whirling instrument (called a centrifuge), which acts to force the oxygen bubbles out of the mixture. The oxygen, which is added to the ship's air, carries water vapor with it, but this can be frozen out and returned to the vat.

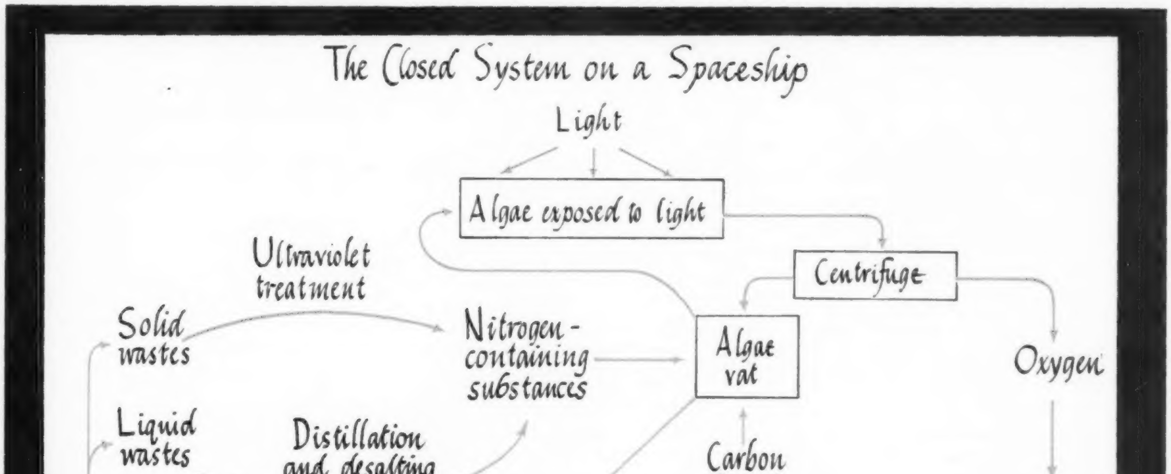
The amount of algae culture required on a space voyage depends on the speed with which the algae can be made to do their work. The most optimistic estimate I've seen supposes that it might be possible to keep two ounces of algae growing in every quart of culture. About 450 pounds of such a culture might then take care of the food and oxygen needs of one man. (Other estimates make the requirement more than 1,000 pounds.)

Add to this the weight of the necessary equipment. There are vats to hold the culture, lamps to light it, pumps to circulate it, refrigerators, calcium oxide, ultraviolet sources, centrifuges, and so on. This might add another 250 pounds, if pains are taken to make everything as light as possible.

This sounds rather heavy. Think of 700 — or possibly even 1,500 — pounds of algae equipment to take care of each man in the crew! But, then, as I pointed out in the last issue of SCIENCE WORLD, all the necessary food, oxygen, and water for a trip to Mars and back, in the absence of algae, would come to about 5 tons, or 10,000 pounds, per man. For longer trips, still more mountainous quantities would be required. In a closed system, the same algae tanks could be sufficient for any length of trip — provided that the spaceship's gardener is able and efficient.



— Illustrations by Paul Granger



By James E. Gunn

Light from the past

By measuring light that has been locked in rocks for millions of years, a scientist is probing into the earth's history

■ In a room on the University of Kansas campus, a young man in a sports jacket and slacks stands before a complicated-looking electronic machine. After checking the various dials to be sure each is correctly set, he turns the machine on. The machine, you might say, is a detective of time. It will record light that has been locked in a rock sample for perhaps millions of years. By so doing, it will reveal the age of the rock sample and furnish important clues to the geological past of the earth.

This new dating method is being shaped by Dr. Edward J. Zeller, a professor who could pass for one of his students. It is one of the latest of a series of tools that scientists have been using to probe into the historical secrets of our planet.

Scientists are interested in knowing not only *what* happened during the earth's past, but *when* it happened and for *how long* it lasted.

Through most of the history of science, there has been little to draw on by way of answering the question "When?" Fossils, for example, indicated sequence, but they didn't tell when or how long. The best scientists could achieve was an educated guess.

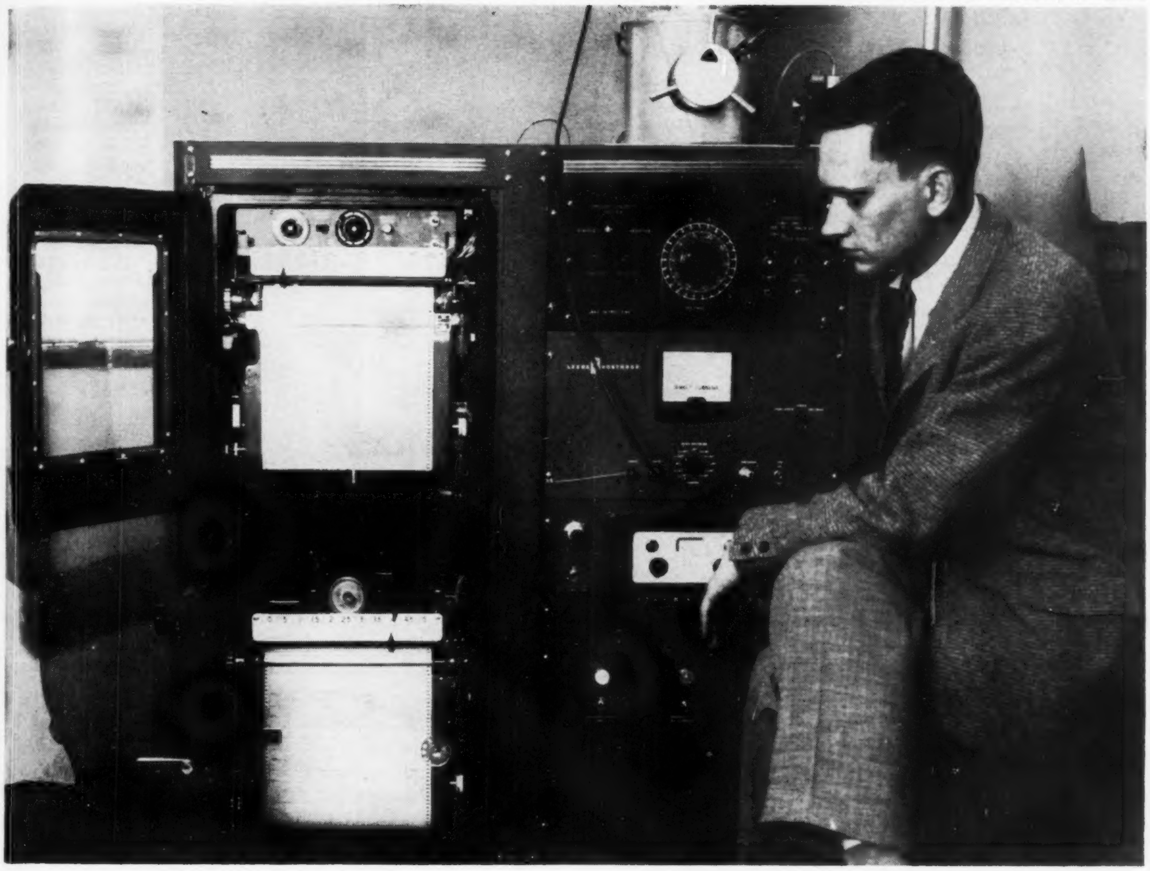
In the early 1900's a new method of dating was suggested. This was based on the discovery of the radioactivity of uranium. Uranium atoms, it was learned, spontaneously give off particles. As a result, the uranium atom, in time, decays into a different atom — an atom of lead. The decay of uranium into lead occurs very slowly and at a constant rate — at the end of 4.5 billion years, for example, only half of a given amount of uranium-238 has changed into lead-206. If a scientist could measure the amount of uranium and lead in a rock, he could compute the length of time necessary for that radioactive decay to have taken place. He would therefore know how long the uranium had been in the rock — and this would be the age of the rock.

All well and good. But here a problem arose. There was natural lead in the rock already. How could anyone distinguish between this lead and the lead that had been formed by the decay of uranium — radiogenic lead?

After 1950 came a new and improved mass spectrometer. This instrument enabled scientists to distinguish between ordinary lead-204 and the radiogenic lead-206 and -207 formed by the decay of uranium. Scientists had a valuable new dating tool.

But this tool could be used only on igneous — that is, once molten — rock. The reason: primary uranium minerals almost never oc-

— Photos from University of Kansas



ROCK SAMPLES ARE DATED by the light they give off in this thermoluminescence machine, assembled by Dr. Edward Zeller.

cur in sedimentary rocks such as limestones. It also required the presence of a sizable percentage of uranium, about one part in two hundred. And its accuracy depended upon the truth of certain assumptions about how much of the radiogenic leads was present when the earth was formed.

About the same time that the uranium-lead method became practicable, another dating method was made available to the scientist interested in "when?" It was noted that radioactive carbon — carbon-14 — is formed by the action of cosmic rays in the atmosphere. The carbon-14 atoms are "breathed in" by vegetation as carbon dioxide. The vegetation is eaten and digested by animals, and people eat both plants and animals. In this way carbon-14 becomes a part of every living organism.

Carbon-14 has a half-life of 5,600 years — that is, in 5,600 years half of a given amount of carbon-14 decays (in the next 5,600 years half of what is left decays, and so on). As the carbon-14 in a living organism decays, it is constantly replaced. Most scientists believe that the proportion of carbon-14 to carbon within the organism is always the same. When the organism dies, the carbon-14 keeps on decaying, but it is not replaced. Thus, by analyzing the proportion of carbon-14 to carbon present, scientists can date a piece of wood from an ancient campfire, a fragment of bone in a cave, or a manuscript in a jar.

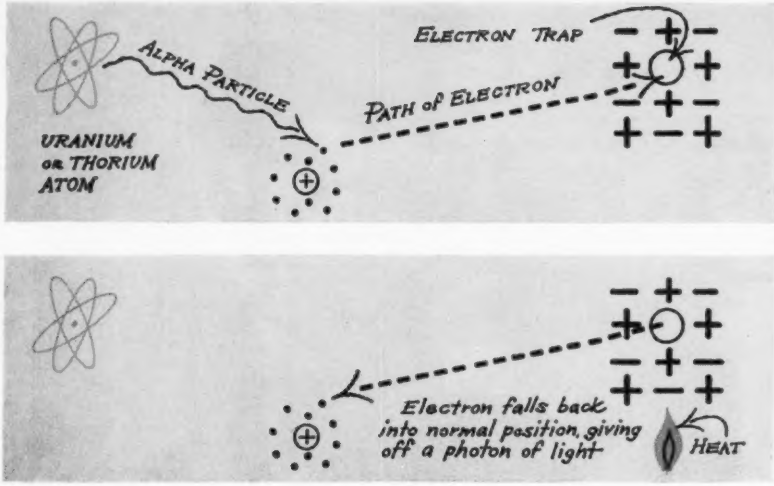
This method, however, is limited to once-living substances. And in specimens older than 50,000 years, there is not enough carbon-14 left to measure. The method also makes an unproved assumption: that the present rate at which the earth is being bombarded by cosmic rays has been constant throughout the period under investigation.

Among promising new dating techniques is the one being developed at the University of Kansas by Dr. Zeller. His method is known as "radioactive dating by thermoluminescence of limestone." It is based on the fact that when limestone (or any semi-conducting crystal, the form in which most non-metallic solids exist) is heated, it glows even before it becomes red-hot. This is known as thermoluminescence.

Why this phenomenon occurs and what use can be made of it are questions that had to wait almost 300 years for answers. Now the generally accepted explanation is that heating releases electrons trapped in the crystals. When they return to their normal positions, the electrons give up excess energy as light.

The famous British physicist and chemist, Robert Boyle, noticed in

Drawings by Wes McKeown



LIGHT IS STORED in rock (*top*) when an alpha particle knocks an electron into a 'trap.' Freed by heat (*bottom*), the electron gives off its extra energy as light.

LIGHT EIGHTY MILLION YEARS OLD is shown in this photo of a heated rock.

1663 that, when heated, diamonds glowed before becoming red-hot. Thorium miners, who placed ore near a campfire, saw the same phenomenon. But it remained only a mineralogical curiosity until 1916, when the present theory was suggested. Not until 1947 did serious research into possible applications begin. It began at the University of Wisconsin.

This is where Dr. Zeller came into the picture. Upon completion of his Ph.D. at Wisconsin in 1951, he was hired to stay there as a project associate. His job: to determine if there was a relationship between the age of the crystal and the amount of light it gave off when heated. If there was, he was to develop techniques for using the phenomenon to date limestone.

Three steps were necessary: (1) to assemble a machine that could measure the small quantities of light given off; (2) to check for each sample the speed with which electrons are knocked out of their normal positions; and (3) to check the capability of each sample to trap electrons.

The heart of the thermoluminescence machine he assembled is the photomultiplier tube developed in 1939 by R.C.A. This electron tube became generally available after World War II. It can detect infinitely small emissions of light and translate them into electrical impulses that can be counted. It is so sensitive that on a dark night it can detect the flame of a match lighted several miles away.

The machine also includes a small oven for heating a sample and a recording device for graphing light emission against temperature.

What causes thermoluminescence? For the answer to this question, we must turn to theory.

Any semi-conducting crystal suffers radiation damage from tiny quantities of self-contained uranium and thorium — as little as one part per million. The alpha particles emitted by the radioactive minerals hit electrons and knock them out of position. Some of the electrons become trapped in imperfections in the crystal — called electron traps.

With this extra energy given them by the alpha particle, the electrons remain in their trap until heat gives them enough additional energy to bounce out. They then "fall back" to their normal position. In "falling" an electron must give up its alpha-particle-derived energy. This it does as a photon of light.

The amount of light given off, then, depends on the number of electrons that have been trapped. And more and more electrons are bound to be trapped with the passage of time. Will a measurement of light, therefore, give the age of a sample of limestone? To answer this question, Dr. Zeller must take into account two other factors that affect the number of trapped electrons:

1. The quantity of uranium and thorium varies from sample to sample. The greater the radioactive content, the faster the electron traps are filled. So Dr. Zeller has to calculate how much radioactivity each sample contains. This he does by measuring alpha particle emissions with a scintillation counter.

2. The number of electron traps varies between samples. To determine how many traps are in a sample, part of it is heated until it is cleared of trapped electrons. Then it is exposed to a known level of radiation for a predetermined time. The amount of light given off by the piece of the radiated sample when heated enables Dr. Zeller to calculate the number of electron traps.

As a source of radiation, Dr. Zeller uses a six-inch cylinder of radioactive cobalt. This has just become available. Until now, Dr. Zeller has been able to arrive at comparative ages only. By measuring a sample's radioactivity, he has been able to determine how fast it fills its electron traps. By measuring the light it gives off when heated, he has been able to say, "So many electrons were trapped." But he has not been able to count how many

traps a sample contains. This sample, he can estimate, seems older than that one, but he hasn't been able to determine exactly how old or how much older. The radioactive cobalt cylinder will fill in the last unknown: how many electron traps?

New applications of this method are constantly opening up. Igneous intrusions — where molten rock has flowed into limestone formations — can be dated by comparing the thermoluminescence of rock far from the intrusions with that close by. The bordering rock would have been cleared of electrons at the time of the intrusion by the heat of the molten rock. Similarly, rock faults can be dated where the rock faces slid against each other, creating heat by friction.

The method received its first "trial by fire" in the coldest place on earth — Antarctica. In an IGY research project, Dr. Zeller and a research assistant, William C. Pearn, spent a month and a half there, seeking the answers to two questions: how long has Antarctica been cold — a few thousand years or many millions; and has cosmic-ray bombardment been constant over the last thirty milleniums?

To answer the first question, the scientists gathered rock samples from beneath the ice. They shipped them home in dry ice, nursed them across the equator, and then sped them into the freezing compartment of a refrigerator on the K.U. campus. Crystals that have remained at very low temperatures exhibit even greater thermoluminescence than usual. By checking thermoluminescence of such crystals, it's possible to determine when, in the past, the temperature rose higher. For the higher temperature would have released the electrons that had been stored up before that time. Coal deposits and other paleontological evidence suggest that the antarctic once had a tropical climate. If so, the samples have been filling their "low temperature" traps only since the frozen continent froze over.

The second question involves ice, which has electron traps just as limestone does. Because it contains no uranium or thorium impurities, any trapped electrons would be due to cosmic-ray activity while the snow was accumulating. By taking cores of ice, representing successive snowfalls over many thousands of years, the scientists hoped to have a record of cosmic-ray bombardment.

The story of their expedition is a saga in itself. They were trapped on Taylor Glacier last November 25, when their airplane could not return because of snow. Pearn wrote in his diary: "At about 1:00 P.M. we began to get a strong wind. We were in the middle of the glacier, the best landing spot, and there was nothing to do but pitch the tent and get in it. We're still in it, and the wind is still strong. It's 10:45 P.M. We are marooned — it's hard to say for how long. Today it's not so funny. If only the wind would quit. If the tent springs a leak we've had it. I've begun listening for small rips."

The next morning — 48 hours late — the plane returned.

But this is the story of a scientific search that has its own thrills and adventure. What were the results of the experiments?

The cosmic-ray experiments were unsuccessful. The places where the ice samples were taken weren't cold enough. Electrons knocked into traps by cosmic rays had been released by the comparative warmth. The average temperature at MacMurdo Sound is 0° F., at Little America, —16° F. Dr. Zeller believes results might be possible, with better equipment, at the South Pole. There, the average temperature is —60° F.

Preliminary results with the rock samples, however, indicate that Antarctica didn't warm up during the last interglacial period — between eighteen and twenty thousand years ago. Further experiments will provide even more definite data.

One hit, one miss — in scientific experiments this is a very good batting average, indeed.

DRESSED IN FUR PARKAS, Dr. Edward J. Zeller and research assistant William C. Pearn pose on University of Kansas campus. Like most antarctic explorers, Dr. Zeller came down with the worst cold of his life on returning home from the polar ice cap. Oddly enough, most explorers suffer no diseases at all while in Antarctica. The reason probably has nothing to do with cold, since many men spend their time inside warm camps below the surface. The real cause is not known, but one theory holds that one of the antarctic lichens may produce a super-effective antibiotic. But that is yet another story.

Science in the news

Fifth U. S. moon probe proves successful

On its fifth try, the U.S. succeeded in sending a space probe to the vicinity of the moon. Pioneer IV, weighing slightly more than 13 pounds, sped past the moon forty-one hours after leaving the launching pad. It then headed toward the sun to become the second man-made planet. About two months earlier, the Soviet Union's 795-pound Mechta had entered an orbit around the sun after passing within 5,000 miles of the moon.

Pioneer IV was launched from Cape Canaveral by a four-stage Army rocket called Juno II. The rocket worked almost perfectly. There was a slight aiming error, however. And the speed was about 100 miles an hour less than expected. As a result, the gold-plated cone that was Pioneer IV went a bit wide of the mark. It missed the moon by about 37,000 miles. Scientists had hoped to put it within 15,000 to 20,000 miles of that body.

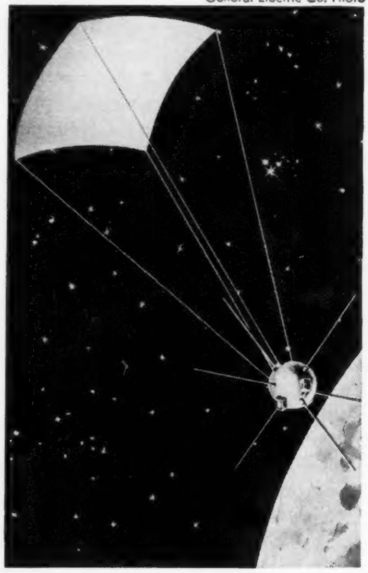
From the start, the probe's instruments worked perfectly. Its radio transmitter sent a steady stream of scientific data back to the earth. The probe reached a top speed of about 24,900 miles an hour. As it climbed toward the moon, its speed was gradually slowed by the tug of the earth's gravity. But the initial speed was great enough to enable Pioneer IV to break free from its earthly bonds. It was the first U.S. vehicle to do so.

Scientists immediately set to work analyzing information coming from the space capsule. Early indications were that it was successfully measuring the extent and energy of radiation in space. Two tiny Geiger counters were carried for this purpose. Scientists hoped for detailed data on the two belts of earth-circling radiation discovered by previous space probes.

Farther out in space, Pioneer IV was equipped to detect clouds of hot, energetic gas that are ejected by eruptions on the sun. These are believed by some scientists to cause radio blackouts on the earth and the auroras—flickering lights in the skies.

Pioneer IV also carried other instruments. One, smaller than a match, was to determine whether any barriers to radio communication exist in space. Fade-outs of the radio signals of Pioneer III, which reached an altitude of some 65,000 miles, led scientists to wonder about such barriers.

General Electric Co. Photo



Solar sail may propel future spaceship. It would use sun's rays as propellant.

Sun's rays may power sailing spaceships

Spaceships may someday sail from planet to planet, much as a sailboat scoots across the water. But the sailing spaceships will be propelled by the sun's rays rather than the wind.

Over the years, several scientists have proposed equipping spaceships with sails. The purpose: to provide them with enough extra power to travel to the planets and return. So much of a space vehicle's fuel is used up in escaping the earth's gravitation that very little is left for travel beyond.

One of the most recent sailing schemes comes from an engineer at the General Electric Company. It would work this way:

A very thin plastic sail folded inside a space vehicle would unfurl after the vehicle reached outer space. The sail would catch particles of light, known as photons, which stream from the sun at 186,000 miles a second. When these light particles fall on a material and are absorbed by it, they exert radiation pressure on it. If the sail's thin plastic sheet was aluminized on one side, says the engineer, it would reflect light as a mirror does and would double radiation pressure.

As an example, a spaceship could be equipped with a 400-by-400-foot sail weighing less than 100 pounds. The ship might first be sent into an earth-circling orbit under ordinary rocket power. Then the sail would be unfolded. The sail would increase the ship's speed by 350 miles an hour each day. In two months, the ship's speed would reach 25,000 miles an hour. This is the velocity needed to escape the earth's gravitational pull. From there on, it would be "smooth sailing" to planets.

The development of a solar sail is still a long way off. But space experts believe it can be a simple, inexpensive, and lightweight means of propelling vehicles millions of miles through space.

Science committee urges more deep-sea research

The sea presents a challenge to man approaching that of space. With this idea in mind, a committee of the National Academy of Sciences urged the United States to double its activities in deep-sea research within the next ten years. It recommended the expenditure of $651 million during this period in addition to the current annual rate of $23 million.

"We know less about many regions of the oceans today than we know about the lunar surface," the committee reported. Some of the areas that ocean research might directly benefit include:

Food resources. How many fish are in the seas? Where do they breed, migrate, feed? When scientists know the answers, they'll be able to "farm" the seas — cultivate fish as food, "fertilize" sea areas to enrich their marine life, and transplant desirable fish from one sea region to another. By such methods, the sea may feed exploding populations of the future.

Weather control. More information is needed on the interchange of ocean air and the slow mixing of warm and cold ocean currents. With this data, scientists will be able to make long-range forecasts of weather and climate. Perhaps eventually they will learn to modify storms and redirect winds. For the oceans greatly influence the earth's weather.

Military defense. Soon submarines armed with long-range missiles will be prowling the seas. To detect these submarines efficiently, we need to learn far more about the ocean depths than we now know. In fact, the profile of the ocean floor must be completely mapped.

Scientists find giraffe has odd blood system

The giraffe's long neck puts a heavy burden on the animal's heart and blood-circulation system. Its heart must pump blood eight to ten feet uphill to its brain. This requires a blood pressure of four times normal human blood pressure. Yet neither the animal's heart nor blood vessels seem to suffer.

To find out why, scientists at the Albert Einstein College of Medicine in New York City made an intensive study of giraffes. Here's what they found:

An extra-thick heart muscle provides the enormous power needed to pump large amounts of blood without strain.

Highly elastic arteries in the animal are not damaged by the tremendous pumping pressure. (Nor are the arteries clogged with fat, as are those of human beings who have high blood pressure. This is probably because the giraffe is a vegetarian and doesn't eat foods with a high fat content.)

A small organ in the giraffe's head reduces blood pressure, thereby keeping the brain's delicate blood vessels from bursting.

Special valves and muscles in the giraffe's blood system help to prevent dizziness when sudden up-and-down movements of the animal's head cause blood to drain from it.

The giraffe study may provide clues to human heart and blood-circulation troubles.

Galaxy catalogue will supply data on universe

A new catalogue of the galaxies is being compiled by astronomers at the California Institute of Technology. The reference book deals with sizes and distances so great they stagger the imagination.

A galaxy is a swarm of billions of stars, each a sun like ours. Galaxies are drawn together in clusters by gravitation. How many millions of galaxies there are is not known.

Some 40,000 of the brightest known galaxies and about 10,000 clusters of galaxies will be shown in the catalogue by charts. The charts are being traced from photographic plates taken through telescopes. They will show the number of galaxies in each cluster, the compactness of the cluster, and its relative distance from the earth. Largest cluster seen so far—the Como Cluster—contains 11,000 individual galaxies.

The galaxy catalogue is also expected to provide new information on:

- The distribution and amount of cosmic dust in our own galaxy, the Milky Way. By determining how much dust they must look through, astronomers can more accurately judge distances. Dust affects the "brightness" of the galaxies. And brightness is a yardstick for measuring cosmic distances.
- The distribution of intergalactic dust—the vast clouds of dust between the galaxies.
- The existence (or non-existence) of "clusters of clusters" of galaxies. If these superclusters do exist, they would prove that gravitation extends throughout the visible universe. But some recent evidence indicates that gravitation doesn't operate when distances between galaxies are greater than five million light years (30 billion billion miles).

It took ten years of observation and sky-mapping by Cal Tech astronomers to gather the data for the catalogue. The project was partly supported by the Office of Naval Research.

Four new space vehicles are in the works

Four new rocket vehicles will be used for future space exploration by the National Aeronautics and Space Administration.

The first available will be a two-stage vehicle using an Atlas ICBM as the first stage. Its purpose: to put a 3,000-pound satellite into orbit.

Two three-stage vehicles, named Vega and Centaur, will also have the Atlas as their first stage. They will be used for flights to the moon, Mars, and Venus. Centaur's second stage will burn hydrogen as fuel. Hydrogen's extra energy is expected to increase the vehicle's chances of reaching Mars and Venus.

Further in the future is a five-stage rocket with a thrust of six million pounds. It will be able to carry a man to the moon and back. Combined with a nuclear-powered rocket, it could probably take a 55,000-pound payload to Mars.

Fishhooks help trace history of Hawaii

Fishhooks, ranging in length from one-half inch to five inches, are helping to shed light on Hawaii's past. Archeologists from Honolulu's Bishop Museum have found fishhooks on the islands that they estimate to date back as much as 1,200 years.

Scientists made carbon-14 tests of charcoal found at one fishhook site. The charcoal dated back to A.D. 957. In a layer of earth below the site, the archeologists found signs of human habitation. From this they concluded that man had lived there as early as A.D. 750.

News in brief

- Indians in the Southwest are cooking with sunlight. Six Indian tribes in Arizona and New Mexico are baking their tortillas with the latest solar-radiation units. Solar "ovens" heat food by concentrating the sun's rays on one spot. Researchers at the University of Wisconsin developed the special solar-radiation units for use in areas where both poverty and sunlight are widespread.

- Messy ink stains in fingerprinting can be eliminated by a new process called fingerprint "casting." The person to be fingerprinted dips his fingers in a bottle of solvent nylon plastic. After a few minutes, the solution dries into a casting, which is then stripped off. Fingerprints are permanently embedded in the hardened nylon plastic. The liquid plastic can also be sprayed on the fingers, if desired.

- Scientists are bouncing radio signals off the tails of meteors. The purpose: to find ways to improve radio transmission. A transmitter tracks the path and speed of a hurtling meteor. It then flashes its signal to the meteor's tail. The radio signal is reflected to receiving stations on the ground. In ordinary radio transmission, charged layers of the atmosphere bounce radio waves back to the earth, deflecting them across continents and oceans. But storms often interfere with this process. Perhaps meteor tails may provide substitute "bouncers."

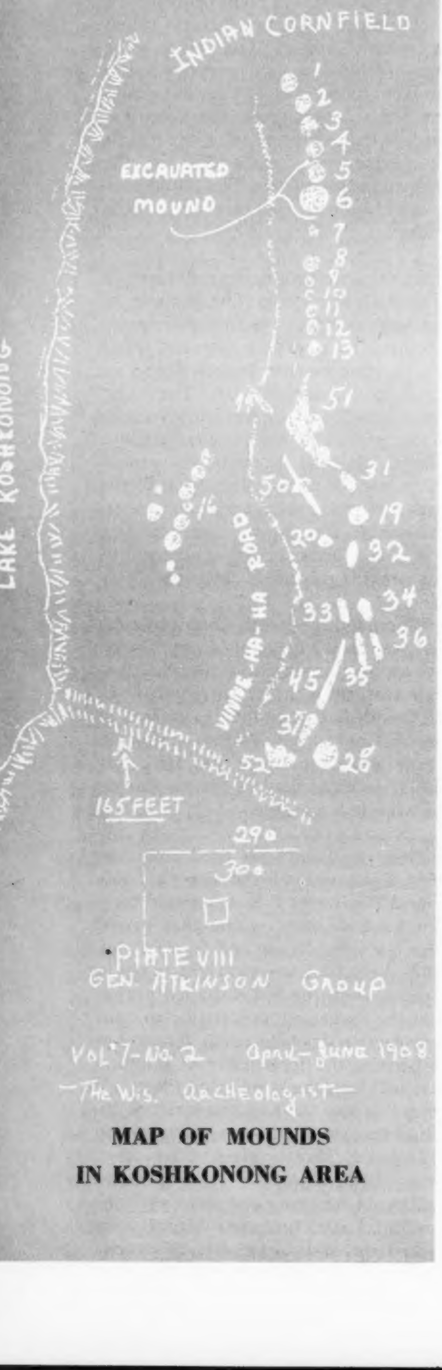
- Where did the North American Eskimo come from? Probably from Siberia, says an anthropologist at the Smithsonian Institution in Washington, D. C. He found that stone tools excavated at early Eskimo and pre-Eskimo sites in the North American arctic are strikingly similar to those used in Siberia during the Middle Stone Age.

- First satellite to be fired from the West Coast was the Air Force's 1,300-pound Discoverer I. It was aimed for a new kind of orbit — one that passed over both the North and South Poles. Since the earth rotates at right angles to a polar orbit, the bullet-shaped projectile was expected eventually to pass over every part of the earth. It was thus to become the forerunner of satellites that will scan the entire globe with TV "eyes." It also was first of a series of satellites that would attempt to hurl a man into space. Shortly after it was fired from Vandenberg Air Force Base in California, tracking stations "lost" the satellite. Later, spasmodic signals were picked up, indicating that Discoverer had achieved orbit.

Young scientists

An archeological adventure

By Rosemary Zickerman, Fort Atkinson (Wis.) High School
Teacher: Jack Cummings



MAP OF MOUNDS IN KOSHKONONG AREA

■ The city of Fort Atkinson, Wisconsin, is located near a lake of considerable size, Lake Koshkonong, along whose shores can be found a great number of Indian mounds. One group of these mounds lies directly beneath the village of Vini-Ha-Ha on the eastern shore. Several have been covered by homes, as is the case of the particular mound with which I was concerned.

This mound, which lies on the property of William Schaefer Jr., was brought to the attention of the University of Wisconsin when Mr. Schaefer, digging for a basement beneath his house, uncovered traces of several human skeletons. The University sent Mr. Hall, a member of the Wisconsin Archeological Society and curator of the Lincoln-Tallman Museum in Janesville, Wisconsin, to investigate. Then, in 1957, he was forced to leave the mound to carry out a program of unearthing the site of an ancient Indian village to the north of the Lake.

The mound remained in this semi-exposed state until the fall of 1957. At that time Mr. Schaefer notified the University that if they wished to continue work on the mound they should contact him. When he received no reply, he notified the Fort Atkinson high school of his position, not wishing to destroy the burial uselessly. It was here that I first heard about the possibility of attempting a project in the field of archeology, through Mr. Cummings, my biology instructor. When I learned of the circumstances, I was delighted to have the opportunity to pursue this work in the field of biology, the subject in which my greatest interest lies.

After observing the mound and giving much thought to just what I wanted to accomplish, I decided to try to excavate as much of the mound as time and the foundation of the house would allow. Then I would remove the skeletons, along with any other artifacts, and reconstruct the mound just as I found it, so that it might be displayed at the high school.

The actual work of digging was done after school with small hand-picks, soft paint brushes, several knives, and a small screw driver. During the few weeks allowed for excavation, I estimate that I put in 75 hours of work and removed approximately one ton of dirt, some of which was sifted to recover small bits of pottery, bone, projectile points, etc., that might have escaped detection. Unfortunately, due to the shortage of time allowed by Mr. Schaefer for excavation, I was not able to sift as completely as I wanted to and therefore lost several of the smaller bones of the hands and feet.

During excavation, the burial pit yielded two complete skeletons, lying in an extended position, and three bundle-type burials. The extended burials were approximately 52 inches below the surface and the bones were in good condition. The bones of the bundles, however, were in poor condition as a result of being placed above the frost line at a depth of only 18 to 22 inches. This indicates a possibility that these particular Indians might have died during the winter months and, because the ground was frozen, were exposed to the elements until they deteriorated. Then, when the ground thawed in the spring, the bones were gathered up in "bundles" and placed in their shallow graves. I found several bits of copper which, unfortunately, were too oxidized for me to determine what type of implements they originally were. I also found a number of pieces of earthen pottery and several projectile points, one of which was lodged in the right femur bone of one of the skeletons. I noticed, too, that the skulls showed a definite cradle-board effect and were considerably flattened in the occipital region.

After photographing the mound area, I removed the skeletons and tagged the bones and other materials for future reference. Next I began to

search for information which, along with my observations, would form a basis for determining age, sex, tribe, etc. According to Mr. Hall, the estimated time of death was between 1,500 and 3,000 years ago. This is considerably older than other specimens obtained from other mounds in this area. To be able to state the age more exactly, I would like to have a bone sample carbon-dated, but the cost is prohibitive. Mr. Hall also believed that, of the two complete skeletons, one was a young adult female and the other a young male, probably in their late teens or early twenties at the time of their death. Judging from my observations and material found in the *Wisconsin Archeologist* magazine, I concluded that the mound was of the type commonly used in the Hopewell culture. If I am correct in this respect, then this is one of only a few mounds in this vicinity that bear a relationship to the Hopewell culture, which is most prevalent in this state along the Mississippi River and the western border.

After compiling a certain amount of information dealing with the Indians, I dealt with the mound itself. In the *Wisconsin Archeologist* and in *Prehistoric America*, I found maps and descriptions of all the mounds in the Koshkonong area. With this information I was able to establish that the mound was one of the General Atkinson group, which consists of a number of effigy, as well as burial, mounds. According to measurements found in *Prehistoric America*, from a known point, I was able to determine that the mound was the burial represented by either the number 5 or 6 of the map of the Atkinson group. It was not possible to determine the location exactly because, in excavation for a road and also for homes, several mounds were either totally or partially destroyed.

As I neared the completion of my project, the next step was the construction of a display case and the actual reconstruction of the mound. The case was built of ¾-inch plywood, 4 feet wide, 8 feet long, and 24 inches deep, with a hinged top containing four glass panels. Into the bottom of this box I put many sheets of newspaper rolled into balls. This paper not only acted as filler, but also as a shock absorber for the delicate skeletons. After covering the bottom with paper, I placed several old window shades over the paper to act as a base for the dirt. Then, on top of these shades, I reconstructed the burial pit.

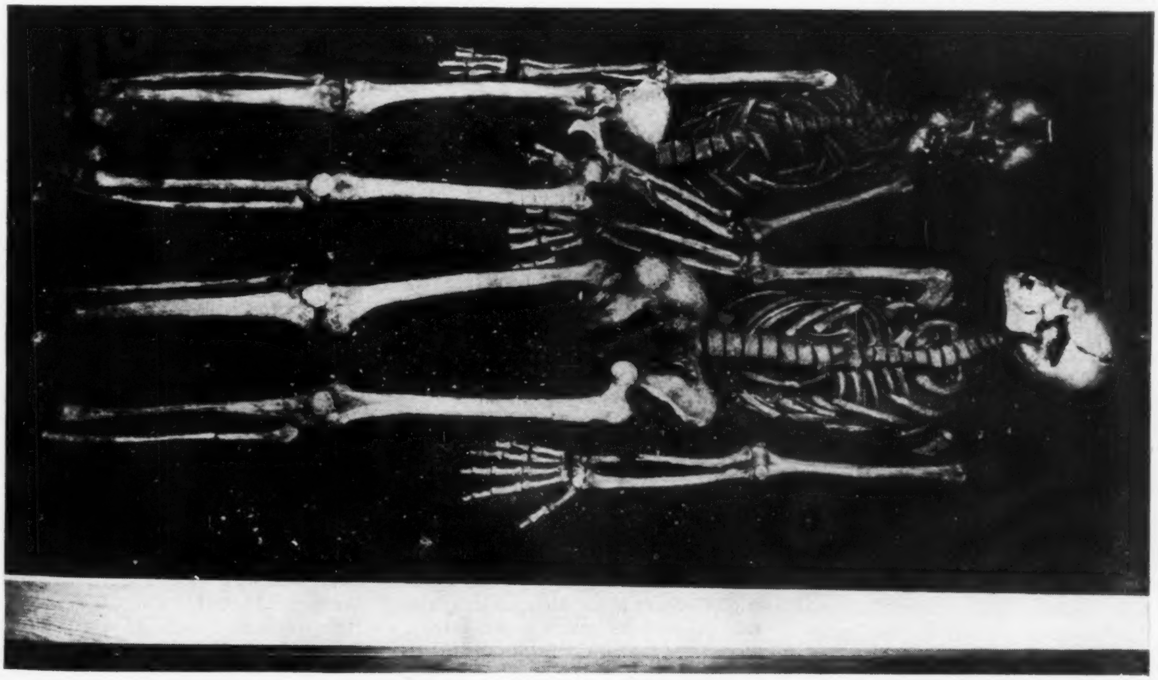
As I began to reassemble the skeletons, I deviated from my original plan to reconstruct the mound "just as I found it," and decided it might be better to mend as many of the bones as possible, especially the skulls and humerus bones. The bones were washed with water to remove the dirt, then, where necessary, were mended with airplane cement. The placement of the skeletons in the case was of special interest to me, as it gave me the opportunity to study skeletal structure at first hand.

To me, this project was a very rewarding experience. Not only was I able to learn more about the Indian culture of this area, but I also gained valuable experience in scientific methods and procedures, which will help me in my future work in biology or in the field of science in general.

Looking for an idea for a project? There may be one right in your own backyard. In the unusual project described here, Rosemary Zickerman of Fort Atkinson (Wis.) High School took over an investigation that an archeologist was unable to complete. With diligent research and painstaking care, Rosemary, under the direction and supervision of her biology instructor, Mr. Jack Cummings, developed a project of which she can be justly proud.

Rosemary's report is printed here just as she wrote it. After you have read it, ask yourself whether or not your community has some unique feature around which you may do a project. — THEODORE BENJAMIN

— Illustrations from Rosemary Zickerman



SKELETONS OF INDIANS (*top, female; bottom, male*) were reassembled by Rosemary Zickerman from bones in burial mound.

By Howard W. Mattson, *Bell Telephone Laboratories*

Flash lamps, but no pictures

How the surprise explosion of a glass tube started two young scientists on a piece of important basic research

■ In recent months, two chemists working at Bell Telephone Laboratories have fired their electronic flash lamps hundreds of times during the course of their research work. There would be nothing unusual about this — except that they haven't exposed a single piece of film the whole time. The flash has been used not to *photograph* research results but to *cause* them.

It all began with a research project undertaken by Dr. John Lundberg. His aim: to find out why a few months' exposure to the summer sun degrades polyethylene plastic to the point where its usefulness is impaired.

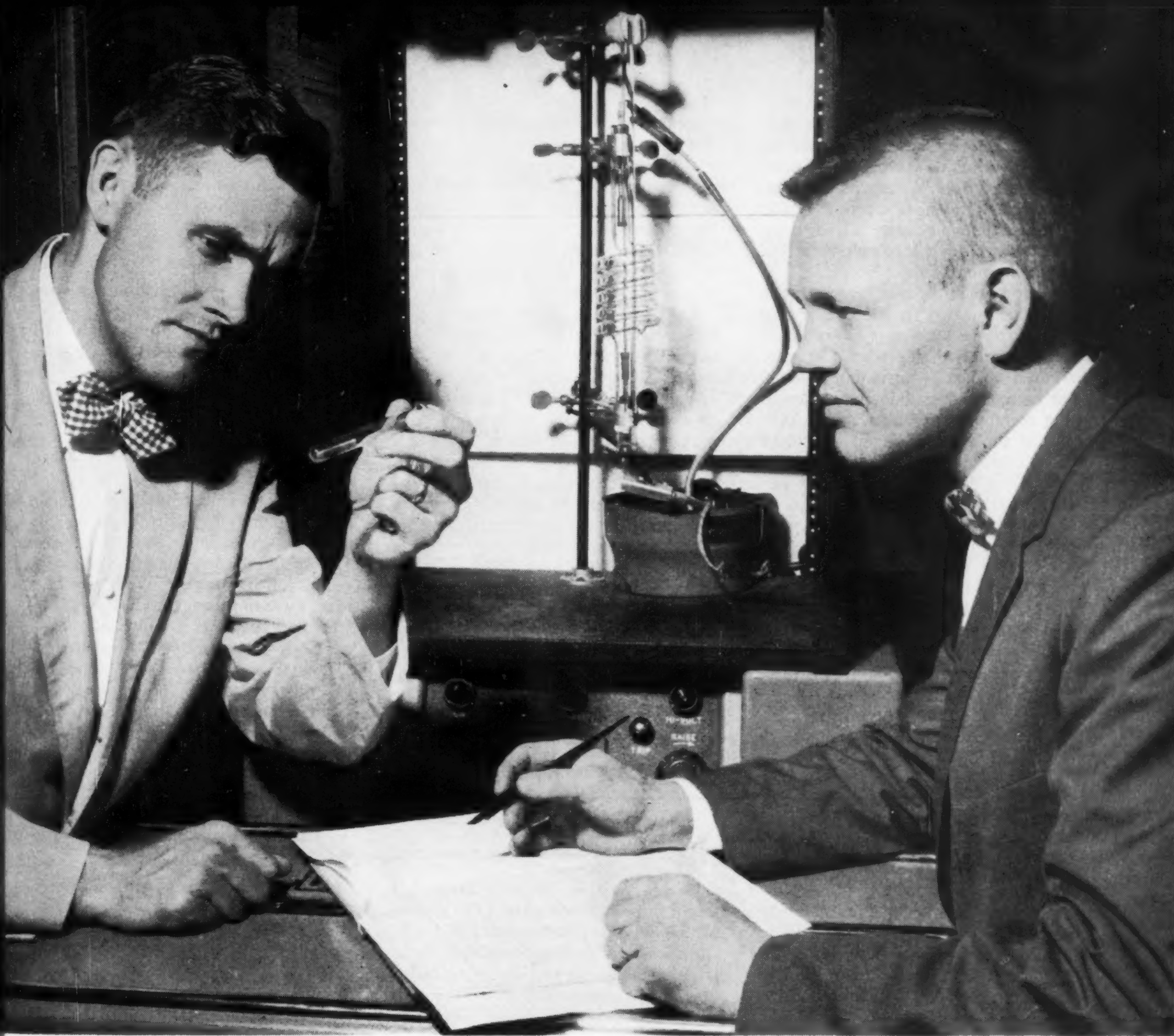
Polyethylene consists of chainlike molecules of carbon and hydrogen. These are chemically similar to those in paraffin wax, only much longer. Dr. Lundberg knew that chainlike chemical compounds of carbon and hydrogen do not absorb sunlight. Therefore, in principle, hydrocarbon plastics like polyethylene should also be unaffected by sunlight. But this was not the case.

To explain this situation, Dr. Lundberg turned his attention to the occasional impurity groups (most of them containing oxygen) that are chemically bound to the polyethylene chain molecules. The effects of these impurity groups were investigated by placing samples of the polyethylene under a vacuum and exposing the samples to ultraviolet light from a mercury vapor lamp. The gases that were liberated during the light-caused reactions were then collected and analyzed. The mercury arcs used were several times brighter than sunlight, and the experiments provided much useful information about how sunlight degradation of polyethylene commences.

However, Dr. Lundberg was interested in knowing what different results might occur when the polyethylene was exposed to much more intense ultraviolet radiation. So he turned to a fellow scientist, Dr. Lloyd Nelson, who was investigating the effects of light waves on chemical reactions and who had a very high intensity flash lamp. This lamp was identical to units that were used during World War II for aerial photography at night. They could be adjusted to give from ten to fifty times as much light as a photographer's electronic flash lamp.

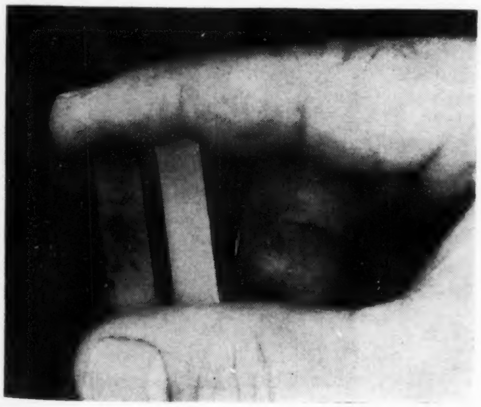
The bulb of the flash apparatus was a coiled tube, somewhat similar in operation to a neon tube. It flashed when brief electric current from a capacitor was applied between the two ends. Sample strips of the plastic to be investigated were sealed inside glass tubes and placed within the coil, which was then flashed. The first flash showed up several dark spots. A second flash was made for good measure.

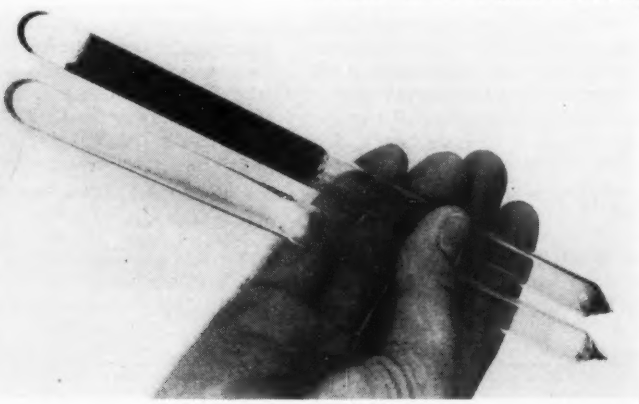
To the surprise of both men, the tube containing the samples exploded, breaking the end off the flash lamp. Here was something to be investigated! Increasing the light intensity had apparently touched off another set of reactions. [*Continued on p.* 24]



INSPECTING A STRIP of polyethylene that has just been exposed to a flash of intense light in the apparatus in the background, Drs. Lloyd Nelson (*left*) and John Lundberg continue experiments that opened a new field of research.

— Photos from Bell Telephone Laboratories





CLOSE-UP VIEW of two strips of polyethylene plastic. The strip at left has been flashed in the apparatus shown in the top picture. Dark areas are decomposed material surrounding dust spots. Dust spots are invisible before being flashed, as shown in strip at right. The two tubes (*above, right*), which contain mineral oil, have just gone through a flash experiment. The blackened tube also contains black tungsten filaments, clear one does not.

As soon as a new flash lamp could be installed, more investigations were begun. The results now appear to open a whole new field of research in high-temperature chemical reactions. The polyethylene experiment can be used to describe the basic principles of the new technique:

Small particles of dust are unintentionally embedded in the plastic material during processing. As far as the flash is concerned, the plastic is transparent, and the light rays pass through with no more effect than that observed using mercury vapor lamps. However, some of the dust particles are "black bodies" that absorb almost all of the light falling on them. These dust particles absorb tremendous amounts of light energy and are heated to temperatures as high as from 3000° to 9000°F. At these temperatures, the plastic around the hot particles is decomposed. This produces various gases, which sometimes are trapped in bubbles by the plastic and at other times burst through the surface. It was these gases which caused the sample tube to explode in the first experiment.

In actual experiments, the "black bodies" are more carefully selected than is dust. Powdered carbon can be used. Also, very fine blackened fibers of tungsten, glass wool, and powdered metals of various types work well. These fibers and particles need not be immersed in plastic, but can be placed in liquids, gases, or even in a vacuum, depending on the type of research.

Research efforts with this new technique can go in two directions: they can investigate the effects of the flash on the light absorbers themselves, or they can investigate the effects on the surrounding material, called the "matrix." If the light absorbers, or "black bodies," are being investigated, they are of a reactive nature (such as coal or powdered metal), and the surroundings are inert. If the matrix is being investigated, the black body is inert (tungsten or platinum fibers or black quartz wool) and the matrix is reactive. Natural gas, "L-P gas," and other gases may be investigated in this way, as can liquids such as mineral oil or other oils. Plastics like polyethylene are examples of reactive solids which can be decomposed with "flash pyrolysis," the name coined for this new technique.

Many of the decomposition products that result from treating materials in this way are fluorescent; that is, they glow greenish-blue under ultraviolet light. The reasons for this are not yet fully understood but are being investigated.

In fact, scientists have just scratched the surface in looking into the many uses of this new method. The possibilities for research application have opened up so fast that no one research group can handle them. And the results in the future can be expected to spread widely into many fields of science.

The practical applications of this new method are also as yet unknown. Perhaps it will open the way for more efficient combustion in motors or to more effective fuels for rockets. Perhaps it will become an inspection technique for impurities in materials. It may prove to be a method of preparing sensitive chemical compounds which up to now have eluded the synthesist.

One thing is almost sure: it will be investigated thoroughly for several years before its full potential is known, and for several more years before practical application is made. Such is the way of basic research.

Viewed under ultraviolet light, flashed strip of polyethylene shows greenish fluorescence, especially around dust particles, which act as heat absorbers.

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If you are considering a career in photography or study in this field to aid other science interests, you will find factual information in *Photography in Your Future*. This Eastman Kodak Company pamphlet lists the many uses of photography in science and the range of job choices for the professional. Check No. 3241.

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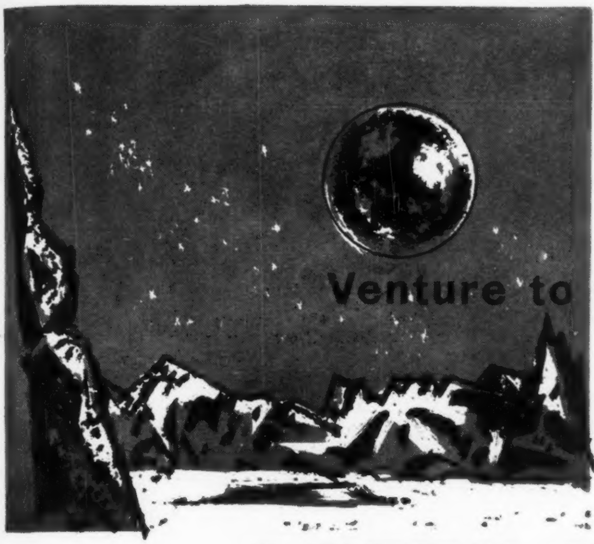
Science fiction



Venture to the moon

GREEN FINGERS

On the three-power expedition to the moon, the Russian botanist was making mysterious trips off alone. He'd had a brilliant idea — but forgotten one very important point

By Arthur C. Clarke

■ I am very sorry, now that it's too late, that I never got to know Vladimir Surov. As I remember him, he was a quiet little man who could understand English but couldn't speak it well enough to make conversation. Even to his colleagues, I suspect he was a bit of an enigma. Whenever I went aboard the *Ziolkovski,* he would be sitting in a corner working on his notes or peering through a microscope, a man who clung to his privacy even in the tight and tiny world of a spaceship. The rest of the crew did not seem to mind his aloofness; when they spoke to him, it was clear that they regarded him with tolerant affection, as well as with respect. That was hardly surprising; the work he had done developing plants and trees that could flourish far inside the Arctic Circle had already made him the most famous botanist in Russia.

The fact that the Russian expedition had taken a botanist to the moon had caused a good deal of amusement, though it was really no odder than the fact that there were biologists on both the British and American ships. During the years before the first lunar landing, a good deal of evidence had accumulated, hinting that some form of vegetation might exist on the moon despite its airlessness and lack of water. The president of the U.S.S.R. Academy of Science was one of the leading proponents of this theory, and being too old to make the trip himself had done the next best thing by sending Surov.

The complete absence of any such vegetation, living or fossil, in the thousand or so square miles explored by our various parties was the first big disappointment the moon had reserved for us. Even those skeptics who were quite certain that no form of life could exist on the moon would have been very glad to have been proved wrong — as of course they were, five years later, when Richards and Shannon made their astonishing discovery inside the great walled plain of Eratosthenes. But *that* revelation still lay in the future; at the time of the first landing, it seemed that Surov had come to the moon in vain.

He did not appear unduly depressed, but kept himself as busy as the rest of the crew studying soil samples and looking after the little hydroponic farm whose pressurized, transparent tubes formed a gleaming network around the *Ziolkovski.* Neither we nor the Americans had gone in for this sort of thing, having calculated that it was better to ship food from Earth than to grow it on the spot — at least until the time came to set up a permanent base. We were right in terms of economics, but wrong in terms of morale. The tiny, airtight greenhouses inside which Surov grew his vegetables and dwarf fruit trees were an oasis upon which we often feasted our eyes when we had grown tired of the immense desolation surrounding us.

One of the many disadvantages of being commander was that I seldom had much chance to do any active exploring; I was too busy preparing reports for Earth, checking stores, arranging programs and duty rosters, conferring with my opposite numbers in the American and Russian ships, and trying — not always successfully — to guess what would go wrong next. As a result, I sometimes did not go outside the base for two or three days at a time, and it was a standing joke that my space suit was a haven for moths.

Perhaps it is because of this that I

can remember all my trips outside so vividly; certainly I can recall my only encounter with Surov. It was near noon, with the sun high above the southern mountains and the new Earth a barely visible thread of silver a few degrees away from it. Henderson, our geophysicist, wanted to take some magnetic readings at a series of check points a couple of miles to the east of the base. Everyone else was busy, and I was momentarily on top of my work, so we set off together on foot.

The journey was not long enough to merit taking one of the scooters, especially because the charges in the batteries were getting low. In any case, I always enjoyed walking out in the open on the moon. It was not merely the scenery, which even at its most awe-inspiring one can grow accustomed to after a while. No — what I never tired of was the effortless, slow-motion way in which every step took me bounding over the landscape, giving me the freedom that before the coming of space flight men only knew in dreams.

We had done the job and were halfway home when I noticed a figure moving across the plain about a mile to the south of us — not far, in fact, from the Russian base. I snapped my field glasses down inside my helmet and took a careful look at the other explorer. Even at close range, of course, you can't identify a man in a space suit, but because the suits are always coded by color and number that makes no practical difference.

"Who is it?" asked Henderson over the short-range radio channel to which we were both tuned.

"Blue suit, Number 3 — that would be Surov. But I don't understand. *He's by himself.*"

It is one of the most fundamental rules of lunar exploration that no one goes anywhere alone on the surface of the moon. So many accidents can happen that would be trivial if you were with a companion — but fatal if you were by yourself. How would you manage, for example, if your space suit developed a slow leak in the small of the back and you couldn't put on a repair patch? That may sound funny; but it's happened.

"Perhaps his buddy has had an accident and he's going to fetch help," suggested Henderson. "Maybe we had better call him."

I shook my head. Surov was obviously in no hurry. He had been out on a trip of his own and was making his leisurely way back to the *Ziolkovski.* It was no concern of mine if Commander Krasnin let his people go out on solo trips, though it seemed a deplorable practice. And if Surov was breaking regulations, it was equally no concern of mine to report him.

During the next two months, my men often spotted Surov making his lone way over the landscape, but he always avoided them if they got too near. I made some discreet inquiries and found that Commander Krasnin had been forced, owing to shortage of men, to relax some of his safety rules. But I couldn't find out what Surov was up to, though I never dreamed that his commander was equally in the dark.

It was with an "I told you so" feeling that I got Krasnin's emergency call. We had all had men in trouble before and had had to send out help, but this was the first time anyone had been lost and had not replied when his ship had sent out the recall signal. There was a hasty radio conference, a line of action was drawn up, and search parties fanned out from each of the three ships.

Once again I was with Henderson, and it was only common sense for us to backtrack along the route that we had seen Surov following. It was in what we regarded as "our" territory, quite some distance away from Surov's own ship, and as we scrambled up the low foothills it occurred to me for the first time that the Russian might have been doing something he wanted to keep from his colleagues. What it might be, I could not imagine.

Henderson found him and yelled for help over his suit radio. But it was much too late; Surov was lying face down, his deflated suit crumpled around him. He had been kneeling when something had smashed the plastic globe of his helmet; you could see how he had pitched forward and died instantaneously.

When Commander Krasnin reached us, we were still staring at the unbelievable object that Surov had been examining when he died. It was about three feet high, a leathery, greenish oval rooted to the rocks with a widespread network of tendrils. Yes — rooted; for it was a plant. A few yards away there were two others, much smaller and apparently dead, since they were blackened and withered.

My first reaction was: "So there *is* life on the moon, after all!" It was not until Krasnin's voice spoke in my ears that I realized how much more marvelous was the truth.

"Poor Vladimir!" he said. "We knew he was a genius, yet we laughed at him when he told us of his dream. So he kept his greatest work a secret. He conquered the Arctic with his hybrid wheat, but *that* was only a beginning. He has brought life to the moon — and death as well."

As I stood there, in that first moment of astonished revelation, it still seemed a miracle. Today, all the world knows the history of "Surov's cactus," as it was inevitably if quite inaccurately christened, and it has lost much of its wonder. His notes have told the full story and have described the years of experimentation that finally led him to a plant whose leathery skin would enable it to survive in vacuum, and whose far-ranging, acid-secreting roots would enable it to grow upon rocks where even lichens would be hard put to thrive. And we have seen the realization of the second stage of Surov's dream, for the cactus which will forever bear his name has already broken up vast areas of the lunar rock and so prepared a way for the more specialized plants that now feed every human being upon the moon.

Krasnin bent down beside the body of his colleague and lifted it.

"What could have happened to him?" he said. "It almost looks as if the plant did it, but that's ridiculous."

The green enigma stood there on the no longer barren plain, tantalizing us with its promise and its mystery. Then Henderson said slowly, as if thinking aloud:

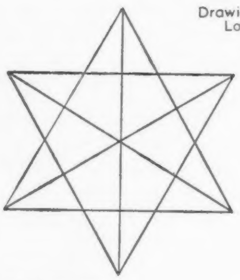
"I believe I've got the answer; I've just remembered some of the botany I did at school. If Surov designed this plant for lunar conditions, how would he arrange for it to propagate itself? The seeds would have to be scattered over a very wide area in the hope of finding a few suitable places to grow. There are no birds or animals here to carry them in the way that happens on Earth. I can only think of one solution — and some of our terrestrial plants have already used it."

He was interrupted by my yell. Something had hit with a resounding clang against the metal waistband of my suit. It did no damage, but it was so sudden and unexpected that it took me utterly by surprise.

A seed lay at my feet, about the size and shape of a plum stone. A few yards away, we found the one that had shattered Surov's helmet as he bent down. He must have known that the plant was ripe, but in his eagerness to examine it he had forgotten what that implied. I have seen a cactus throw its seed a quarter of a mile under the low lunar gravity. Surov had been shot at point-blank range by his own creation.

On the light side

Drawings by LoCurcio



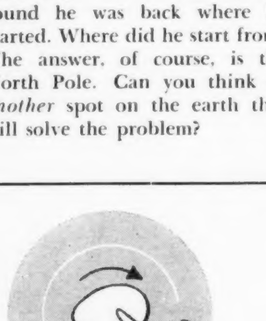
Brain teasers

Count the triangles

This is not as easy as it looks. How many triangles can you find in the six-pointed star above?

The explorer

An old riddle says that an explorer walked a mile south, a mile east, and a mile north, then found he was back where he started. Where did he start from? The answer, of course, is the North Pole. Can you think of *another* spot on the earth that will solve the problem?



Self-starting egg

Place a raw egg (in its shell) on a plate. With your finger and thumb at opposite ends of the egg, give it as strong a spin as you can. Immediately, place your forefinger on top of the egg, as shown above, pressing hard enough to bring the egg to a dead stop. The instant the egg stops spinning, lift the finger. A surprising thing happens. The egg slowly starts turning again!

What starts the egg moving? The answer is that the *inside* of the egg never really stops moving. Your finger stops the shell, but the inertia of the liquid interior keeps it rotating. When you lift your finger, the liquid has enough momentum to turn the shell. If you try the stunt with a hard-boiled egg, you'll find that it won't work, though the egg spins much more rapidly than a raw one.

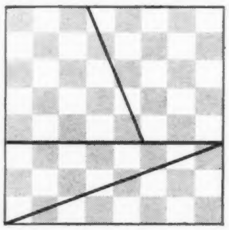


FIG. 1

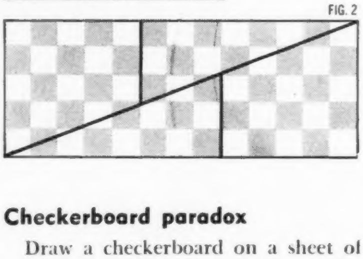


FIG. 2

Checkerboard paradox

Draw a checkerboard on a sheet of graph paper, then cut it into four pieces along the lines indicated in Fig. 1. These four pieces can be rearranged to make the rectangle shown in Fig. 2. Something exceedingly strange has now taken place. The checkerboard contained 64 square units, but the rectangle has 65! Where does the extra square come from? (See Answers.)

Copying fluid

With the aid of a fluid, newspaper photographs and cartoons can be transferred easily from the newsprint to blank sheets of paper. To make the fluid, mix four parts of water with one part of turpentine. Add a bit of soap about the size of a pencil eraser and shake the mixture until the soap is dissolved. The purpose of the soap is to form an emulsion that keeps the turpentine and water (which have different specific gravities) from separating.

To copy a newspaper picture, moisten the picture with the liquid, place a blank sheet of paper on top, then rub the paper vigorously with the bowl of a spoon. The turpentine dissolves enough of the ink so that a reverse impression of the picture is transferred to the paper.

— George Groth

Answers

COUNT THE TRIANGLES: There are 36 triangles.

THE EXPLORER: The explorer starts from a spot 1 plus $\frac{1}{2\pi}$ miles from the South Pole. After walking a mile south, his trek east carries him in a full circle around the pole, so that the final mile north returns him to the original starting point.

CHECKERBOARD PARADOX: The pieces do not fit together snugly to make the rectangle. There is a long, narrow space along the diagonal that is just large enough to equal the area of one square unit. It is interesting to observe that the line segments in this paradox — 3, 5, 8, 13 — form what mathematicians call a Fibonacci series. Each number is the sum of its two preceding numbers. An interesting classroom exercise is to see how many variations of the paradox can be found by constructing it according to other numbers that form a Fibonacci series. For example, the series 4, 6, 10, 16 will make a square that *loses* four units of area when the rectangle is formed.

Edward Lash of Gaylord, Michigan, writes:

What is a carat, and how is it used to measure gold? Does any substance tarnish or discolor gold?

Beans or seeds called carats were once used in weighing precious stones on a balance. Since they were not of uniform size or weight, the results were neither standard nor accurate. After many attempts to simplify and standardize the measuring of gems, the metric carat — equal to 200 milligrams — was introduced (it was adopted in 1913 in the United States). Because of the metric carat, the weights of gems

could be expressed in decimals instead of fractions. In the case of gold, "carat" came to have a different meaning: a twenty-fourth part. Because gold is too soft in its pure form for ordinary use, it is usually alloyed with copper, silver, or platinum. The number of parts of gold in 24 parts of the alloy is expressed in carats. Thus, 24-carat gold is pure gold, and 18-carat gold is 75 per cent gold. Gold does not tarnish in air. It can even go through ordinary fire without changing color. Only a few acids will attack it, notably aqua regia and selenic acid. Both can dissolve gold.

Roberta Lindberg of Norwalk, California, writes:

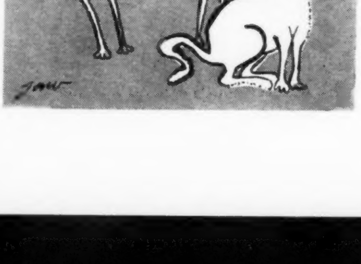
Why does Saturn have rings?

Nobody knows for sure, but this is the theory held by many astronomers: Saturn's rings, which consist of a vast number of small particles, may have been formed by a shattered satellite. Besides its three concentric rings, Saturn has nine satellites revolving around it. At one time the planet may have had a tenth satellite that disintegrated after coming too close to Saturn. The gravitational force of the planet could have set up tidal waves in the satellite that tore it to pieces. If this did happen, say astronomers, the fragments would have assumed an orbit around Saturn similar to the rings.

Ken Leyshon of West Wyoming, Pennsylvania, writes:

Can a cat control its purring or a dog the wagging of its tail?

Cats purr and dogs wag their tails when they are happy or content. These acts show pleasure just as a human being's smile does. But a dog or cat cannot control these actions the way a human can control his smile. Man has intellectual power that enables him to frown when he is actually happy or to smile when he's unhappy. However, it would be extremely difficult, if not impossible, to teach a dog to wag its tail or a cat to purr when the feeling of pleasure was not present.



Sharon August of Encino, California, writes:

Why do we wear light-colored clothing rather than dark clothing in hot weather?

White clothes are far more comfortable than dark clothing because they reflect much more heat. When radiant heat from the sun falls upon a body, some of it is reflected, some passes through the body, and some is absorbed. The body is warmed by the heat that is absorbed. Whereas white clothing reflects most of the heat that strikes it, dark clothing absorbs and retains most of it, making the wearer uncomfortable on a hot day. For the same reason, homes in warm areas are generally painted in light colors.

Tom White of Petaluma, California, writes:

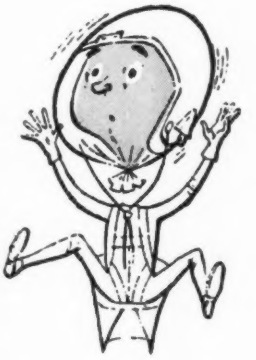
Is hydrofluoric acid the most corrosive acid?

To some materials, yes; to others, no. Hydrofluoric acid is the water solution of hydrogen fluoride, a colorless gas prepared by treating a fluoride with concentrated sulfuric acid. It can eat away concrete, glass, and some metals, but it is not corrosive to some materials, such as lead and paraffin. Generally speaking, hydrofluoric acid is one of the four most corrosive acids. The others: hydrochloric acid, nitric acid, and sulfuric acid.

Questions from readers will be answered here, as space permits. Send to: Question Box, Science World, 575 Madison Avenue, New York 22, N.Y.

The pressure helmet is an important piece of safety equipment for high-altitude flying. But, as these cartoons show, a pilot wearing one faces a ticklish problem –

How does he scratch his nose if it itches?



Wearing a pressure helmet, say pilots, is like having your head separated from your body and in a cellophane bag.

If he opened the face plate at high altitude to get at an itching nose, the pilot would run the risk of explosive decompression.

One test pilot relieves his tickling nose by jamming in the helmet's face plate and rubbing his nose against it.

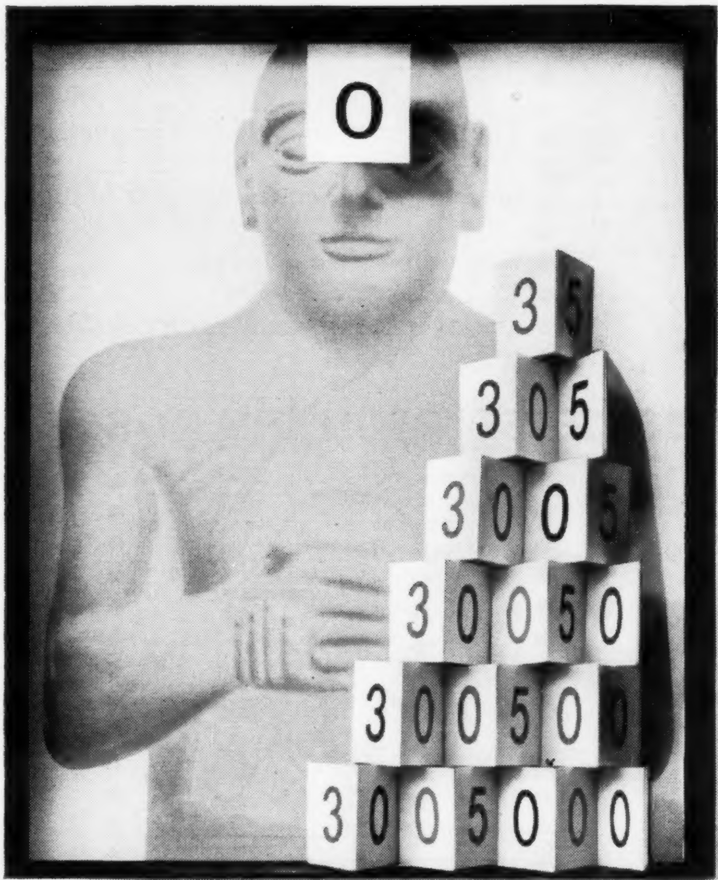
A long nose can be an advantage for relieving an itch. It also makes a handy fog-wiper when the face plate clouds up.

To some pilots an itching nose isn't nearly as bothersome as a running nose. They just have to grin and bear it until they land.

Another exquisite torture is the cold, clammy feeling of perspiration collecting over the helmet's rubber neck seal.

Adapted from New Frontiers, *Spring, 1957, The Garrett Corporation*

MATHEMATICS SERVING MAN



HOW NOTHING BECAME SOMETHING: There was a time when no one could imagine a numeral that stands for nothing you can see, or touch, or count. For thousands of years the ancient Babylonians, scratching cuneiform calculations on wet clay tablets, simply left a space in the middle of such numbers as 305. This made it easy to confuse 3 5 with 35. Around 300 B.C., an unknown scribe jammed the end of his stylus into the clay to mark such a space—3·5—and primitive "zero" was born. More than a thousand years later, the Hindus brought to the court of the Caliph of Baghdad the first zero, a real digit that could be used in addition or subtraction. The Arabs, in turn, introduced zero to medieval Spain and all of Europe. Today we still use this Hindu zero to identify 305—and for newer tasks such as marking the dividing line between plus and minus numbers, as in temperature readings. It is typical of the world of mathematics that the work of scholars centuries ago is still vitally important today.

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How to do it

Nerve impulse demonstrations

Among the questions that arise in biology class during the teaching of the unit on the nervous system are these two: What is the nature of the nerve impulse? How fast do nerve impulses travel along a nerve?

In answer to the first question, the teacher is apt to say that the nerve impulse is a traveling chemical reaction, with an electrical concomitant, along a nerve fiber. But how might the teacher *show* a "traveling chemical reaction"? As for the second question, the speed of a nerve impulse is readily found in the textbook. But how might the class go about finding out for itself?

Demonstrating a traveling chemical reaction: Holding a length of cotton thread by one end, ignite the other end. The flame will travel up the thread to the end you are holding. Raise the question: what caused the flame to move along the thread? Bring out that the energy of the reaction at the point of the flame caused a reaction in the part of the thread adjacent to it. In this way, the reaction traveled up the thread. Ask students to imagine that the moment the flame passed a given point the ashes turned back into thread. This is comparable to what takes place in a nerve fiber.

Finding the speed of a nerve impulse: Have ten students line up in the front of the room. Ask each student to place his index finger close to, but not touching, the small of the back of the person in front of him. Have the student who is last in line act as a timekeeper (he should have a watch with a second hand). Appoint a recorder, who will stand at the blackboard. Then give the following instructions: When the timekeeper is ready, he will touch the back of the student in front of him. When *that* student feels the touch, *he* will immediately touch the person in front of *him*, and so on. When the person at the front of the line feels the touch, he will call "Time." The timekeeper will announce how many seconds it took for the nerve impulse to travel through the nervous systems of the ten students. The recorder will record the time, in seconds, on the board.

This whole procedure should be repeated at least five times. Then, with a ruler or tape measure, measure the approximate distance the impulse traveled through the nervous system of one student (from the small of the back to the brain to the muscle of the arm). Multiply this measurement by ten to obtain the distance the "message" traveled through the ten students. Divide this figure by each of the times recorded on the blackboard to obtain the speed of the nerve impulse in each instance.

Several questions that will lead to further discussion and further reading are bound to arise. Examples:

1. How can you account for the fact that each time the experiment was repeated the speed of the impulse was greater? (This question could lead to the study of synapses and their properties. It could also lead to the manner in which the brain is involved.)

2. How can you account for the discrepancy between the speed given in the textbook and that determined by the experiment? (This question could lead to a study of the methods by which the speed of a nerve impulse is actually measured in the laboratory.)

Simple demonstration of the inverse-square law

A small projection bulb, an automobile headlight lamp, or an arc lamp can be used for this demonstration. (If a six-volt automobile bulb is used, operate it on the eight-volt tap of the secondary of a toy train transformer or other step-down transformer.)

Cut two twelve-inch squares of cardboard or composition board. In the center of one, cut a one-inch-square hole. Now set up the light and the cardboard squares as shown in Fig. 1. The hole in the piece of cardboard should be one foot from the lamp. The second board becomes a screen. With the screen three feet from the lamp, an area of 3 x 3 inches, or nine square inches, will be illuminated. At four feet from the lamp, an area 4 x 4 inches, or sixteen square inches, will be illuminated; at five feet, the lighted area will be 5 x 5 inches. The intensity per square inch will be visibly less as the distance increases. The intensity will vary according to the inverse square of the distance.

Drawing by LoCurcio

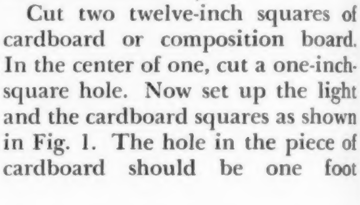
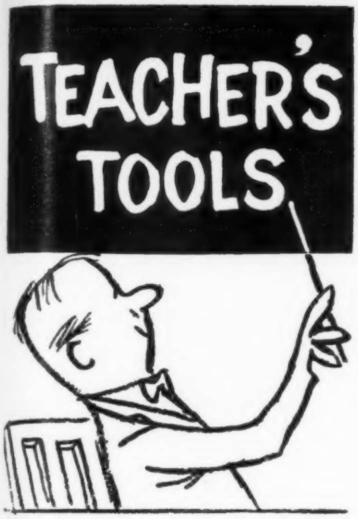


Fig. 1



Hamilton Manufacturing Company introduces an entirely new concept in science laboratory room use. Roto-Lab — based on the lazy-Susan idea — allows one room to serve as a laboratory for three or four related subject areas. Especially developed by Professors Railsback and Skadeland of the University of Illinois to solve a lab space problem on the college level, the Roto-Lab may be the answer to your school's needs. *(For additional information on Roto-Lab, check No. 324A.)*

Kintel, a division of Cohu Electronics, Inc., a leader in the manufacture of closed-circuit and broadcast television equipment for many years, features a closed-circuit television model for science-classroom demonstrations in which every seat in the room becomes "front-row." Demonstration-table work becomes alive and easy to see through various monitor screens placed around the room. Also, actual live demonstrations can be transmitted to your students from various parts of the building. By means of a Zoomar lens, a pinhead can be made the size of the monitor screen. Material viewed through a microscope can also be displayed on the monitor screens. *(If you are interested in closed-circuit TV as a demonstration aid, check No. 324B.)*

Schaar and Company brings you Heat-by-the-Yard, flexible and elastic Heating Tape. Filling a hundred and one needs in many science teaching situations, this handy item can be cut to desired lengths for use on any pipe, vessel, valve, or school science research project. Heat-by-the-Yard consists of a continuous network of resistance wires enclosed in a knitted elastic sleeve of glass fiber. Made in one-half-inch and one-inch widths, it is available in either 25-foot or 50-foot lengths. *(For details on Heat-by-the-Yard, check No. 324C.)*

Modern references and textbook 'tools'

Science Experimenter, published by Science and Mechanics Publishing Company, is a storehouse of ideas that can be used for springtime open houses, extra-credit projects, and local and state science fairs. Including step-by-step plans for some forty science projects, the book should inspire teachers and students to think of hundreds more possible projects. This valuable reference includes such worth-while chapters as "Winning at Science Fairs" and "Preparing for a Science Career." Projects range from photographing stars and satellites or building an accurate chemical balance to collecting fossils. Price: 75 cents. The *Experimenter* may be ordered directly from Science and Mechanics Publishing Co., 450 East Ohio St., Chicago 11, Ill.

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See also: Doerr Glass Co., p. 5-T; American Optical Co., p. 8-T

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AO Reports on Teaching with the Microscope

An old box camera, some cardboard and model airplane cement . . . or do-it-yourself photomicrography.

Without question the microscope and the camera have a certain natural affinity for one another. Everyone, it seems, who has ever looked through a microscope and used a camera has had the desire to apply the one to the other and photograph the invisible detail revealed to his eye.

American Optical profits in a small way from this affinity, manufacturing a truly excellent photomicrographic camera at a most reasonable price. Your request for the $300.00 plus required for one of these precise research instruments would get short shrift, however, from your school administrators. So, without fear of losing business, we can proceed to outline our little plan for a very rudimentary, do-it-yourself photomicrographic camera set-up that would be entirely adequate for preliminary student excursions into the art of photomicrography.

TAKE ANY OLD BOX CAMERA

Our photomicrographic set-up will consist of an ordinary box camera for holding the film and a cardboard box arrangement for focusing. Any old clunker of a box camera will do... just make sure it has a setting for time exposure.

CONSTRUCTING ADAPTERS:

Construct two cardboard adapters, one inch high out of stiff cardboard (1/16" approx.) and model airplane cement (see fig. 1). Holes should be cut to fit snugly over microscope eyepiece.

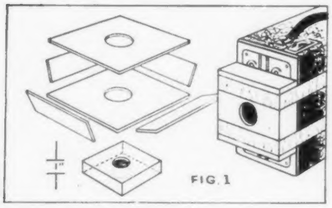

FIG. 1

PROCEDURE FOR ADAPTING CAMERA:

Remove lens from camera, (reflecting surfaces of the camera lens will produce glare, or "hot spots" on film). Tape one adapter to camera, (see fig. 1). Load camera with standard panchromatic roll film.

PROCEDURE FOR CONSTRUCTING FOCUSING DEVICE:

Construct eight inch high cardboard viewer by cementing three sides around second adapter (see fig. 2). After three sides are cemented, mount ground glass (ground side down) to cardboard shelf and then cement on fourth side.

NOTE: Ground glass *must be* same distance from face of adapter on viewer as film plane of camera is from face of its adapter (see fig. 2).

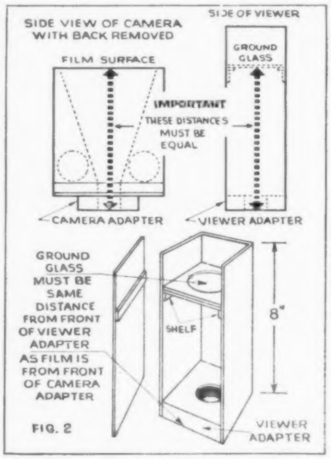

FIG. 2

PROCEDURE FOR TAKING PHOTOMICROGRAPHS:

1. Focus specimen under microscope. Be certain that the field is brightly and evenly illuminated. Then place focusing device over the eyepiece and focus microscope until image is as sharply defined as possible on the ground glass.

2. Turn *off* substage illuminator, or interpose black, opaque paper between light source and substage. Replace focusing device with camera. Set camera to time exposure and open shutter.

3. Turn *on* substage illuminator or remove black opaque paper . . . this will expose the film. After proper exposure, turn *off* substage illuminator or reintroduce black paper. Close shutter before removing camera. The camera shutter is used *only* to make the camera lightproof when it is not in use. Do not use shutter to expose film. The tripping of the shutter would create a tremor resulting in a blurred photograph. Also, be careful not to set up any other vibrations that will shake camera during exposure.

This do-it-yourself photomicrographic set-up is very convenient and very adequate. It's always ready and no elaborate adjustments are necessary.

NOTE: The following notes on microscopes, illumination and exposure are offered as guides.

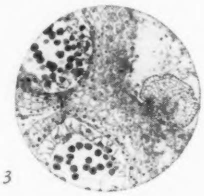

Fig. 3

A. MICROSCOPE: The microscope should be equipped with achromatic objectives and preferably, though not essential, an iris diaphragm and condenser. The AO Spencer 66 series student microscope provides just the ticket... its rugged, dependable and has the same mechanical and optical precision found in laboratory microscopes. If your lab already has number 66's you're all set to go ahead with your camera set-up. If not, you may want some information. Just write to American Optical Company, Instrument Division, Dept. 0252, Buffalo 15, N. Y., and ask for brochure SBTI.

B. ILLUMINATION: A substage attached illuminator will guarantee the evenly illuminated field necessary for good photographs...the negative will show up uneveness even where the eye will fail to notice it. Here, we are using the AO Spencer 66B Microscope equipped with the low-cost 616 attachable substage illuminator.

C. EXPOSURE: Exposure is a matter of experience. If you use the microscope-illuminator set described above, you can use the following information as a guide. The Photomicrograph (see fig. 3), was taken at 100X magnification (10X eyepiece, 10X objective) with three second exposure using Kodak Verichrome Pan film. Our trials showed that one to three second exposures yielded good results. For other magnifications you can use the following rule of thumb as a guide.

1. 430X magnification (10X eyepiece, 43X objective). Expose 4 times as long as 100X.
2. 970X magnification (10X eyepiece, 97X oil immersion objective). Expose 2 times as long as 430X.

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